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MULTIPLE REGRESSION TECHNIQUE FOR Pth DEGREE POLYNOMIALS WITH AND WITHOUT LINEAR CROSS PRODUCTS

by John William Davis George C. Marshall Space Flight Center Marshall Space Flight Center, Ala. 35812 (NASA-TN-D-7422) MULTIPLE REGRESSION TECHNIQUE FOR Pth DEGREE POLYMONINALS HITH AND HITHOUT LINEAR CROSS PRODUCTS (NASA) 197 p HC \$4 25 CSCL 12A

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16. ABSTRACT

A multiple regression technique has been developed by which the nonlinear behavior of specified independent variables can be related to a given dependent variable. The polynomial expression can be of Pth degree and can incorporate N independent variables. Two cases are treated such that mathematical models can be studied both with and without linear cross products. The resulting surface fits can be used to summarize trends for a given phenomenon and provide a mathematical relationship for subsequent analysis.

To implement this technique, separate computer programs have been developed for the case without linear cross products and for the case incorporating such cross products which evaluate the various constants in the model regression equation. In addition, the significance of the estimated regression equation is considered and the standard deviation, the F statistic, the maximum absolute percent error, and the average of the absolute values of the percent of error evaluated.

The computer programs and their manner of utilization are described. Sample problems are included to illustrate the use and capability of the technique which show the output formats and typical plots comparing computer results to each set of input data.

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TABLE OF CONTENTS

		Page
I.	INTRODUCTION	. 1
II.	MULTIPLE REGRESSION TECHNIQUE WITHOUT CROSS PRODUCTS	. 2
	A. Introduction	. 2
III.	MULTIPLE REGRESSION TECHNIQUE WITH CROSS PRODUCTS	. 8
	A. Introduction	. 9
IV.	SIGNIFICANCE OF THE ESTIMATED REGRESSION EQUATIONS	. 18
	A. Introduction	. 19
V.	SUMMARY	. 22
APPE	NDIX A – MULTIPLE REGRESSION PROGRAM FOR CASE WITHOUT CROSS PRODUCTS	. 23
	A. Input Data	. 25 : 25
APPE	NDIX B – MULTIPLE REGRESSION PROGRAM FOR CASE WITH CROSS PRODUCTS	. 60
	A. Input Data	. 62
REFE	RENCES	. 99

LIST OF ILLUSTRATIONS

Title

Page

Figure

Ι.	Program deck sequence	26
2.	Operation of the computer program (noncross product)	44
3.	Comparison of input and computer values for illustrative problem without cross products	59
4.	Operation of the computer program (cross product)	82
5.	Comparison of input and computed values for illustrative problem with cross products	97
	LIST OF TABLES	
Table	Title	Page
1.	Analysis of Variance (With and Without Cross Products)	19
2.	Program Listing (Without Cross Products)	27
3.	Input Data, Dependent Variable Values	57
4.	Output Data Listing for Illustrative Problem (Case Without Cross Products)	58
5.	Program Listing (With Cross Products)	64
6.	Input Data, Dependent Variable Values	95
7.	Output Data Listing for Illustrative Problem (Case With Cross Products)	96

DEFINITION OF SYMBOLS

Symbol

Definition

 A_0

model equation intercept coefficient

 B_N

matrix quantity

 $B_{\mathbf{P}}$

model equation coefficients

 b_0

defined quantity

 b_{NP}

regression model coefficients

 $c_{N-1,N}$

regression model cross product coefficients

F

F statistic

 K_N

cross product model equation terms

k

cross product technique parameter pertaining to degrees of freedom

N

number of independent variables

n

number of data points

P

degree of equation

R

multiple correlation coefficient

 S_{NN}

matrix quantity

 S_{NY}

matrix quantity

 S_{YY}

total sum of squares

S(Reg)

regression sum of squares

S(Res)

residual sum of squares

S

variance

Y

value of dependent variable

DEFINITION OF SYMBOLS (Concluded)

Symbol

Definition

у

difference in observed and mean value of dependent variable

 z_N

value of Nth independent variable

z_{NP}

difference in observed and mean values to the Pth power for the Nth

independent variable

 $|\epsilon|_{AVG}$

average absolute percent error

 $\sum_{i=1}^{\infty}$

 $\sum_{i=1}^{n}$, summation from the first to the nth term

Superscript

С

calculated value

mean value

Subscript

i = 1, 2, ... n

j = 1, 2, ... N

MULTIPLE REGRESSION TECHNIQUE FOR Pth DEGREE POLYNOMIALS WITH AND WITHOUT LINEAR CROSS PRODUCTS

I. INTRODUCTION

The investigation of physical processes and requirements for data analysis methods frequently requires the use of mathematical models which describe the processes. The model can be formulated such that certain variables interact according to physical theories associated with the particular process, or it may contain identified independent variables and unknown parameters. The relationship of the parameters identified in the model can be evaluated using the statistical tool commonly referred to as regression analysis. In principle, it should be possible to establish complex curves or surfaces for higher order multiple variable functions by regression techniques to summarize trends in data and to provide a means of predicting similar phenomena. Furthermore, such a technique might be used to establish unknown laws or relationships.

Most statistical textbooks treat the problem of linear multiple variable regression and of nonlinear regression of one independent variable. However, the study of many complex physical problems requires a method capable of determining nonlinear regression of multiple independent variables. By this means, an analytical representation of the observed data is provided which can be used in subsequent analysis.

The general procedure in regression analysis is to take partial derivatives of a specific model-dependent minimizing function. The set of equations obtained by setting these partial derivatives equal to zero is frequently referred to as the normal equations. If the normal equations are not transcendental in any of the unknown parameters, they can be solved by the usual algebraic methods. It is this situation which is of concern here.

Within this report a method is presented for evaluating multiple variable regression for Pth degree polynomials with and without linear cross products. Implementation of the technique, including error diagnostics has been accomplished on the UNIVAC 1108 computer. Program listings and illustrative example problems are given in the appendices.

The method developed is used in problems requiring the determination of mathematical relationships describing complex curves or surfaces from known physical data. Initial applications of this technique have concerned the external aerodynamics of aircraft and space vehicles and the internal aerodynamics of transonic wind tunnels and have produced excellent results. Applications in almost any other field of study should be expected to be equally as useful.

II. MULTIPLE REGRESSION TECHNIQUE WITHOUT CROSS PRODUCTS

A. Introduction

The derivation of a matrix solution for evaluating multiple variable regression for Pth degree polynomials without cross products is presented in Reference 1. In this section this solution is discussed for the general case where the polynomial expression can be of Pth degree with N independent variables. The mathematical procedures represent a rigorous least squares evolution of input data centered about the mean.

B. Regression Analysis Development

Assuming the observed dependent variable is to be estimated by the following model:

$$Y_{i}^{c} = A_{0} + (b_{11} Z_{1i} + b_{12} Z_{1i}^{2} + \dots + b_{1P} Z_{1i}^{P})$$

$$+ (b_{21} Z_{2i} + b_{22} Z_{2i}^{2} + \dots + b_{2P} Z_{2i}^{P})$$

$$+ \dots + (b_{N1} Z_{Ni} + b_{N2} Z_{Ni}^{2} + \dots + b_{NP} Z_{Ni}^{P})$$
(1)

where i = 1, 2, ..., nth set of data, and the intercept $A_0 = b_{10} + b_{20} + ... + b_{N0}$

For any given independent variable \boldsymbol{Z}_{N} , the mean value is given by

$$\overline{Z}_{N} = \frac{\sum Z_{Ni}}{n}$$
 (2)

If the input data are centered about the mean the model equation (1) becomes

$$Y_{i}^{c} = b_{0} + (b_{11} z_{11i} + b_{12} z_{12i} + ... + b_{1P} z_{1Pi})$$

$$+ (b_{21} z_{21i} + b_{22} z_{22i} + ... + b_{2P} z_{2Pi})$$
(3)

+ ... +
$$(b_{N1} z_{N1i} + b_{N2} z_{N2i} + ... + b_{NP} z_{NPi})$$
 (3) (Concluded)

Where, for convenience, the following quantities, which are indicated in equation (3), are defined by

$$b_{0} = (b_{10} + b_{11} \overline{Z}_{1} + b_{12} \overline{Z}_{1}^{2} + \dots + b_{1P} \overline{Z}_{1}^{P})$$

$$+ (b_{20} + b_{21} \overline{Z}_{2} + b_{22} \overline{Z}_{2}^{2} + \dots + b_{2P} \overline{Z}_{2}^{P})$$

$$+ \dots + (b_{N0} + b_{N1} \overline{Z}_{N} + b_{N2} \overline{Z}_{N}^{2} + \dots + b_{NP} \overline{Z}_{N}^{P})$$

$$(4)$$

$$z_{11i} = Z_{1i} - \overline{Z}_{1}$$

$$z_{12i} = Z_{1i}^{2} - \overline{Z}_{1}^{2}$$

$$\vdots$$

$$z_{1Pi} = Z_{1i}^{P} - \overline{Z}_{1}^{P}$$

$$\vdots$$

$$z_{21i} = Z_{2i} - \overline{Z}_{2}$$

$$z_{22i} = Z_{2i}^{2} - \overline{Z}_{2}^{2}$$

$$\vdots$$

$$z_{2Pi} = Z_{2i}^{P} - \overline{Z}_{2}^{P}$$

$$\vdots$$

$$z_{N1i} = Z_{Ni} - \overline{Z}_{N}$$

$$z_{N2i} = Z_{Ni}^{2} - \overline{Z}_{N}^{2}$$

$$\vdots$$

$$z_{NPi} = Z_{Ni}^{P} - \overline{Z}_{N}^{P}$$

(5)

The classical form of the least squares minimizing function is

$$M = \sum_{i} (Y_i - Y_i^c)^2$$
 (6)

This result follows from the least squares principle that the best representation of the input data is that which makes the sum of the squares of the residuals a minimum. The condition which fulfills this requirement is that the partial derivatives of this function with respect to each of the unknowns be zero. Hence, the following normal equations for i = 1, 2, ... n are written:

$$\frac{\partial M}{\partial b_{0}} = 0$$

$$\frac{\partial M}{\partial b_{11}} = 0$$

$$\frac{\partial M}{\partial b_{21}} = 0$$

$$\frac{\partial M}{\partial b_{21}} = 0$$

$$\frac{\partial M}{\partial b_{22}} = 0$$

$$\vdots$$

$$\frac{\partial M}{\partial b_{1P}} = 0$$

$$\frac{\partial M}{\partial b_{1P}} = 0$$

$$\frac{\partial M}{\partial b_{2P}} = 0$$

$$\frac{\partial M}{\partial b_{NP}} = 0$$

Through the use of the normal equation $\frac{\partial M}{\partial b_0} = 0$ it can be shown that

$$b_0 = \overline{Y} = \frac{\sum Y_i}{m} \tag{8}$$

The following quantity is now defined for the difference in the observed value of Y_i and the mean value of the observed values:

$$y_i = Y_i - \overline{Y}$$
 (9)

Then, through the use of the remaining normal equations, the following matrix solution for the unknown constant of the independent variables is obtained.

$$\begin{bmatrix} B_1 \\ B_2 \\ \vdots \\ B_N \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & \cdots & S_{1N} \\ S_{21} & S_{22} & \cdots & S_{2N} \\ \vdots & \vdots & & \vdots \\ S_{N1} & S_{N2} & S_{NN} \end{bmatrix}^{-1} \begin{bmatrix} S_{1y} \\ S_{2y} \\ \vdots \\ S_{ny} \end{bmatrix}$$

$$\begin{bmatrix} [NPx1] \end{bmatrix} \begin{bmatrix} [NPxNP] \end{bmatrix} \begin{bmatrix} [NPx1] \end{bmatrix}$$

where the following matrix quantities are given by:

$$B_{1} = \begin{bmatrix} b_{11} \\ b_{12} \\ \vdots \\ b_{1P} \end{bmatrix}$$

$$B_{2} = \begin{bmatrix} b_{21} \\ b_{22} \\ \vdots \\ b_{2P} \end{bmatrix}$$

$$\vdots$$

$$B_{N} = \begin{bmatrix} b_{N1} \\ b_{N2} \\ \vdots \\ b_{NP} \end{bmatrix}$$

$$(11)$$

$$S_{1j} = \begin{bmatrix} \sum_{z_{11i}}^{z_{11i}} \sum_{j_{11i}}^{z_{21i}} \sum_{j_{2i}}^{z_{12i}} \sum_{j_{2i}}^{z_{22i}} \sum_{j_{2i}}^{z_{2i}} \sum_{j_{2i}}^{z_{2i}}^{z_{2i}} \sum_{j_{2i}}^{z_{2i}}^{z_{2i}} \sum_{j_{2i}}^{z_{2i}}^{z_{2i}} \sum_{j_{2i}}^{z_{2i}}^{z_{2i}}^{z_{2i}} \sum_{j_{2i}}^{z_{2i}}^$$

(12)

$$S_{1y} = \begin{bmatrix} \sum_{z_{11i}} y_i \\ \sum_{z_{12i}} y_i \\ \vdots \\ \sum_{z_{1Pi}} y_i \end{bmatrix}$$

$$S_{2y} = \begin{bmatrix} \sum_{z_{21i}} y_i \\ \sum_{z_{22i}} y_i \\ \vdots \\ \sum_{z_{2Pi}} y_i \end{bmatrix}$$

$$\vdots$$

$$S_{Ny} = \begin{bmatrix} \sum_{z_{N2i}} y_i \\ \vdots \\ \sum_{z_{NPi}} y_i \end{bmatrix}$$

$$\vdots$$

$$\sum_{z_{NPi}} y_i$$

$$\vdots$$

$$\sum_{z_{NPi}} y_i$$

$$\vdots$$

Having determined the matrix solution indicated by equation (10), the intercept A_0 of the fitted model expression may be determined as:

$$A_{0} = \overline{Y} - (b_{11} \overline{Z}_{1} + b_{12} \overline{Z}_{1}^{2} + \dots + b_{1P} \overline{Z}_{1}^{P}) - (b_{21} \overline{Z}_{2} + b_{22} \overline{Z}_{2}^{2} + \dots + b_{2P} \overline{Z}_{N}^{P}) - \dots - (b_{N1} \overline{Z}_{N} + b_{N2} \overline{Z}_{N}^{2} + \dots + b_{NP} \overline{Z}_{N}^{P})$$
(14)

C. Discussion

As noted by Graybill [2], there are an infinite number of solutions to the model relationship. However, only one solution must be found to have a useful result. Also note that the solution presented to the higher order multiple regression problem is a function of parameters such as the sum of the squares, cross products, and linear values similar to previously developed solutions for linear regression. In this case, one finds a more complex result with nested matrices, which becomes practical only in combination with digital computer techniques.

As discussed in Appendix A, a computer program has been developed to evaluate the unknown constants in the model equation with the solution specified by equation (10), as well as certain diagnostics reflecting the significance of the estimated regression equation which will be considered in Section IV.

It is required in the application of this technique that the S matrix be nonsingular and that the input data are reasonably well behaved. It is also required that $n \ge NP$. That is, the number of data points n must be equal to or greater than the number of unknown parameters in the model equation.

Many sets of physical data have been studied using the previously mentioned computer program. Results have generally been excellent and it is felt that the technique can be highly useful in many fields of endeavor.

III. MULTIPLE REGRESSION TECHNIQUE WITH CROSS PRODUCTS

A. Introduction

The regression technique developed in Section II for Pth degree polynomials with N independent variables has proven to be extremely useful in correlating experimental wind tunnel data and aiding subsequent analysis. However, in certain applications the inclusion of cross products for the various independent variables can enhance the value of the technique. Such a case occurs when it is desired to optimize the dependent variable of the fitted mathematical expression with respect to the various independent variables. In such a case the determination of maximum and minimum values by solving for the critical points through the use of the necessary and sufficient conditions (that the first and second partial derivation of the response variable with respect to each of the independent variables be identically equal to zero) can only be determined when cross products are included in the model equation; otherwise the effect of all other independent variables is lost when the partial derivative with respect to a given independent variable is evaluated.

To deal with this and other similar problems, a method is developed in this section which treats all combinations of linear cross products for each of the N independent variables as well as the polynomial terms previously discussed in Section II. Higher order cross product terms could, in principle, be treated, although such a development is beyond the scope of the present work. The method for fitting polynomials with linear cross products is presented without formal derivation. However, the development is similar to that shown in Reference 1.

B. Regression Analysis Development with Linear Cross Products

Consider the following model:

$$Y_{i}^{c} = A_{0} + (b_{11} Z_{1i} + b_{12} Z_{1i}^{2} + \dots + b_{1P} Z_{1i}^{P})$$

$$+ (b_{21} Z_{2i} + b_{22} Z_{2i}^{2} + \dots + b_{2P} Z_{2i}^{P})$$

$$+ \dots + (b_{N1} Z_{Ni} + b_{N2} Z_{Ni}^{2} + \dots + b_{NP} Z_{Ni}^{P})$$

$$+ (C_{12} Z_{1i} Z_{2i} + c_{13} Z_{1i} Z_{3i} + \dots + C_{1N} Z_{1i} Z_{Ni})$$

$$+ (C_{23} Z_{21} Z_{3i} + C_{24} Z_{2i} Z_{4i} + \dots + C_{2N} Z_{2i} Z_{Ni})$$

$$+ \dots + (C_{N-1} Z_{Ni} Z_{N-1})_{i} Z_{Ni})$$

$$(15)$$

where i = 1, 2, ..., nth set of data, and the intercept $A_0 = b_{10} + b_{20} + ... + b_{n0}$. This model represents a polynomial expression of Pth degree with N independent variables and contains all combinations of linear cross products for each of the N independent variables.

If equal quantities are added and subtracted in equation (15), namely, those of the form $b_{NP}\overline{Z}_{N}^{P}$ and $C_{ji}\overline{Z_{j}}\overline{Z_{i}}$, (where j = 1, 2, ..., N-1) it can be shown that the model equation is equivalent to:

$$Y_i^c = K_{1i} + B_{1i} + K_{2i} + B_{2i} + \dots + K_{Ni} + B_{Ni}$$
 (16)

where

$$K_{1i} = b_{10} + b_{11} \overline{Z}_{1} + b_{12} \overline{Z}_{1}^{2} + \dots + b_{1P} \overline{Z}_{1}^{P} + C_{12} \overline{Z}_{1} \overline{Z}_{2} + C_{13} \overline{Z}_{1} \overline{Z}_{3} + \dots + C_{1N} \overline{Z}_{1} \overline{Z}_{N}$$

$$K_{2i} - b_{20} + b_{21} \overline{Z}_{2} + b_{22} \overline{Z}_{2}^{2} + \dots + b_{2P} \overline{Z}_{2}^{P} + C_{23} \overline{Z}_{2} \overline{Z}_{3} + C_{24} \overline{Z}_{2} \overline{Z}_{4} + \dots + C_{2N} \overline{Z}_{2} \overline{Z}_{N}$$

$$\vdots$$

$$K_{Ni} = b_{N0} + b_{N1} \overline{Z}_{N} + b_{N2} \overline{Z}_{N}^{2} + \dots + b_{NP} \overline{Z}_{N}^{P} + C_{N-1,N} \overline{Z}_{N-1} \overline{Z}_{N}$$

$$B_{1i} = b_{11} z_{11i} + b_{12} z_{12i} + \dots + b_{1P} z_{1Pi} + C_{12} z_{12i}^{+} + C_{13} z_{13i}^{+} + \dots + C_{1N} z_{1Ni}^{+}$$

$$B_{2i} = b_{21} z_{21i} + b_{22} z_{22i} + \dots + b_{2P} z_{2Pi} + C_{23} z_{23i}^{+} + C_{24} z_{24i}^{+} + \dots + C_{2N} z_{2Ni}^{+}$$

$$\vdots$$

$$B_{Ni} = b_{N1} z_{N1i} + b_{N2} z_{N2i} + \dots + b_{NP} z_{NP} + C_{N-1,N} z_{N-1,N_{i}}^{+}$$

$$(18)$$

The jth mean value terms in equation (18) are given by

$$\overline{Z}_{j} = \sum \frac{Z_{ji}}{n}$$
 (19)

$$\overline{Z_{j}}\overline{Z_{N}} = \sum \frac{Z_{ji}Z_{Ni}}{n}$$
 (20)

and for convenience z and z⁺ terms in equation (18) have been defined as:

$$z_{11i} = Z_{1i} - \overline{Z}_{1}$$

$$z_{12i} = Z_{1i}^{2} - \overline{Z}_{1}^{2}$$

$$\vdots$$

$$z_{1Pi} = Z_{1i}^{P} - Z_{1}^{P}$$

$$z_{21i} = Z_{2i} - \overline{Z}_{2}$$

$$z_{22i} = Z_{2i}^{2} - \overline{Z}_{2}^{2}$$

$$\vdots$$

$$z_{2Pi} = Z_{2i}^{P} - Z_{2}^{P}$$

$$z_{N1i} = Z_{Ni} - Z_{N}$$

$$\vdots$$

$$z_{N2i} = Z_{Ni}^{1} - Z_{N}^{1}$$

$$\vdots$$

$$z_{NFi} = Z_{Ni} - Z_{N}^{P}$$

$$z_{12i}^{+} = Z_{1i} Z_{2i} - \overline{Z_{1}Z_{2}}$$

$$z_{13i}^{+} = Z_{1i} Z_{3i} - \overline{Z_{1}Z_{N}}$$

$$\vdots$$

$$z_{1Ni}^{+} = Z_{1i} Z_{Ni} - \overline{Z_{1}Z_{N}}$$

$$(22)$$

$$z_{23i}^{+} = Z_{2i} Z_{3i} - \overline{Z_{2}Z_{3}}$$

$$z_{24i}^{+} = Z_{2i} Z_{4i} - \overline{Z_{2}Z_{4}}$$

$$\vdots$$

$$z_{2Ni}^{+} = Z_{2i} Z_{Ni} - \overline{Z_{2}Z_{N}}$$

$$\vdots$$

$$z_{N-1,N_{i}}^{+} = Z_{N-1,i} Z_{Ni} - \overline{Z_{N-1}Z_{N}}$$

$$\begin{cases} (22) \\ (Concluded) \end{cases}$$

Regrouping equation (2) the following is obtained

$$Y_i^c = b_0 + B_{1i} + B_{2i} + \dots B_{Ni}$$
 (23)

where

$$b_0 = K_{1i} + K_{2i} + \dots + K_{Ni}$$
 (24)

Through the use of the normal equations resulting from the least squares minimizing function it is found that

$$b_0 = \overline{Y} = \frac{\sum y_i}{n} \tag{25}$$

The difference in the observed value and the mean value of the observed values of the dependent variable is again denoted by:

$$y_i = Y_i - \overline{Y}$$
 (26)

Then the following matrix solution for the unknown constants of the model equation can be obtained through the use of the normal equations:

$$\begin{bmatrix} B_{1} \\ B_{2} \\ \vdots \\ B_{N} \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & \dots & S_{1N} \\ S_{21} & S_{22} & \dots & S_{2N} \\ \vdots & \vdots & & \vdots \\ S_{N1} & S_{N2} & \dots & S_{NN} \end{bmatrix} \begin{bmatrix} S_{1Y} \\ S_{2Y} \\ \vdots \\ S_{NY} \end{bmatrix}.$$

$$[Mx1]$$

$$[MxM]$$

$$[Mx1]$$

where

$$M = NP + N!/2(N-2)!$$
 (28)

and the various matrix quantities are given by:

$$B_{1} = \begin{bmatrix} b_{11} \\ \vdots \\ b_{1P} \\ c_{12} \\ \vdots \\ c_{1N} \end{bmatrix}$$

$$B_{2} = \begin{bmatrix} b_{21} \\ \vdots \\ b_{2P} \\ c_{23} \\ \vdots \\ c_{2N} \end{bmatrix}$$
(29)

$$S_{11} = \begin{bmatrix} \sum_{z_{11i}} z_{11i} & \cdots & \sum_{z_{11i}} z_{1Pi} & \sum_{z_{11i}} z_{12i}^{\dagger} & \cdots & \sum_{z_{11i}} z_{1Pi}^{\dagger} \\ \sum_{z_{1} z_{1}^{\dagger} z_{11i}^{\dagger} & \cdots & \sum_{z_{1} z_{1}^{\dagger} z_{1Pi}^{\dagger}} & \sum_{z_{1} z_{1}^{\dagger} z_{1}^{\dagger} z_{1}^{\dagger} & \cdots & \sum_{z_{1} z_{1}^{\dagger} z_{1Pi}^{\dagger}} \\ \sum_{z_{1} z_{1}^{\dagger} z_{1}^{\dagger} i_{1}^{\dagger} & \cdots & \sum_{z_{1}^{\dagger} z_{1}^{\dagger} z_{1Pi}^{\dagger}} & \sum_{z_{1}^{\dagger} z_{1}^{\dagger} z_{1}^{\dagger} z_{1}^{\dagger} & \cdots & \sum_{z_{1}^{\dagger} z_{1}^{\dagger} z_{1Pi}^{\dagger}} \\ \sum_{z_{1}^{\dagger} z_{1}^{\dagger} z_{1}^{\dagger} i_{1}^{\dagger} & \cdots & \sum_{z_{1}^{\dagger} z_{1}^{\dagger} z_{1Pi}^{\dagger}} & \sum_{z_{1}^{\dagger} z_{1}^{\dagger} z_{1}^{\dagger} z_{1}^{\dagger} & \cdots & \sum_{z_{1}^{\dagger} z_{1}^{\dagger} z_{1Pi}^{\dagger}} \\ \sum_{z_{2}^{\dagger} z_{1}^{\dagger} z_{1}^{\dagger} i_{1}^{\dagger} & \cdots & \sum_{z_{2}^{\dagger} z_{1}^{\dagger} z_{1Pi}^{\dagger}} & \sum_{z_{2}^{\dagger} z_{1}^{\dagger} z_{1}^{\dagger} z_{1Pi}^{\dagger}} & \sum_{z_{2}^{\dagger} z_{1}^{\dagger} z_{1}^{\dagger} z_{1Pi}^{\dagger}} \\ \sum_{z_{2}^{\dagger} z_{1}^{\dagger} z_{1}^{\dagger} i_{1}^{\dagger} & \cdots & \sum_{z_{2}^{\dagger} z_{1}^{\dagger} z_{1Pi}^{\dagger}} & \sum_{z_{2}^{\dagger} z_{1}^{\dagger} z_{1}^{\dagger} z_{1Pi}^{\dagger}} & \sum_{z_{2}^{\dagger} z_{1}^{\dagger} z_{1Pi}^{\dagger}} & \sum_{z_{2}^{\dagger} z_{1}^{\dagger} z_{1Pi}^{\dagger}} \\ \sum_{z_{2}^{\dagger} z_{1}^{\dagger} z_{1}^{\dagger} i_{1}^{\dagger} & \cdots & \sum_{z_{2}^{\dagger} z_{1}^{\dagger} z_{1Pi}^{\dagger}} & \sum_{z_{2}^{\dagger} z_{1}^{\dagger} z_{1Pi}^{\dagger}} & \sum_{z_{2}^{\dagger} z_{1}^{\dagger} z_{1Pi}^{\dagger}} & \sum_{z_{2}^{\dagger} z_{1}^{\dagger} z_{1Pi}^{\dagger}} \\ \sum_{z_{2}^{\dagger} z_{1}^{\dagger} z_{1}^{\dagger} i_{1}^{\dagger} & \cdots & \sum_{z_{2}^{\dagger} z_{1}^{\dagger} z_{1Pi}^{\dagger}} & \sum_{z_{2}^{\dagger} z_{1}^{\dagger} z_{1Pi}^$$

$$S_{12} = \begin{bmatrix} \sum_{z_{11i}} z_{21i} & \cdots & \sum_{z_{11i}} z_{2p_i} & \sum_{z_{1p_i}} z_{23i} & \cdots & \sum_{z_{1p_i}} z_{2h_i} \\ \vdots & \sum_{z_{1p_i}} z_{21i} & \cdots & \sum_{z_{1p_i}} z_{2p_i} & \sum_{z_{1p_i}} z_{23i}^{+} & \cdots & \sum_{z_{1p_i}} z_{2h_i}^{+} \\ \vdots & \sum_{z_{12i}} z_{21i} & \cdots & \sum_{z_{12i}} z_{1p_i} & \sum_{z_{12i}} z_{23i}^{+} & \cdots & \sum_{z_{1p_i}} z_{2h_i}^{+} \\ \vdots & \sum_{z_{1Ni}} z_{21i} & \cdots & \sum_{z_{1Ni}} z_{2p_i} & \sum_{z_{1Ni}} z_{23i}^{+} & \cdots & \sum_{z_{1Ni}} z_{2h_i}^{+} \\ \vdots & \vdots & \sum_{z_{2p_i}} z_{21i}^{+} & \cdots & \sum_{z_{2p_i}} z_{2p_i} & \sum_{z_{2p_i}} z_{23i}^{+} & \cdots & \sum_{z_{2p_i}} z_{2h_i}^{+} \\ \vdots & \vdots & & \sum_{z_{2p_i}} z_{21i}^{+} & \cdots & \sum_{z_{2n_i}} z_{2p_i} & \sum_{z_{2n_i}} z_{2n_i}^{+} & \sum_{z_{2n_i}} z_{2n_i}^{+} \\ \vdots & \vdots & & \sum_{z_{2n_i}} z_{21i} & \cdots & \sum_{z_{2n_i}} z_{2p_i} & \sum_{z_{2n_i}} z_{2n_i}^{+} & \sum_{z_{2n_i}} z_{2n_i}^{+} \\ \vdots & \vdots & & \sum_{z_{2n_i}} z_{2n_i} & \sum_{z_{2n_i}} z_{2n_i} & \sum_{z_{2n_i}} z_{2n_i}^{+} & \sum_{z_{2n_i}} z_{2n_i}^{+} \\ \vdots & \vdots & & \sum_{z_{2n_i}} z_{2n_i} & \sum_{z_{2n_i}} z_{2n_i} & \sum_{z_{2n_i}} z_{2n_i} & \sum_{z_{2n_i}} z_{2n_i} \\ \sum_{z_{2n_i}} z_{2n_i} & \sum_{z_{2n_i}} z_{2n_i} & \sum_{z_{2n_i}} z_{2n_i} & \sum_{z_{2n_i}} z_{2n_i} & \sum_{z_{2n_i}} z_{2n_i} \\ \vdots & \sum_{z_{2n_i}} z_{2n_i} \\ \sum_{z_{2n_i}} z_{2n_i} & \sum_{z_{$$

$$S_{1N} = \begin{bmatrix} \sum_{z_{11i}} z_{N1i} & \cdots & \sum_{z_{11i}} z_{NPi} & \sum_{z_{11i}} z_{N-1,Ni} & \cdots & \sum_{z_{1Pi}} z_{N-1,Ni} & \cdots & \sum_{z_{1Pi}} z_{NPi} & \sum_{z_{1Pi}} z_{N-1,Ni} & \cdots & \sum_{z_{1Pi}} z_{N-1,Ni} & \cdots & \sum_{z_{1Pi}} z_{NPi} & \sum_{z_{1Pi}} z_{N-1,Ni} & \cdots & \sum_{z_{1Ni}} z_{NPi} & \sum_{z_{1Ni}} z_{N-1,Ni} & \cdots & \sum_{z_{1Ni}} z_{NPi} & \sum_{z_{1Ni}} z_{N-1,Ni} & \cdots & \sum_{z_{2Ni}} z_{NPi} & \sum_{z_{2Ni}} z_{N-1,Ni} & \cdots & \sum_{z_{2Ni}} z_{N-1,Ni} & \cdots & \sum_{z_{2Ni}} z_{NPi} & \sum_{z_{2Ni}} z_{N-1,Ni} & \cdots & \sum_{z_{2Ni}} z_{N-1$$

$$S_{1y} = \begin{bmatrix} \sum_{z_{11i}} y_i \\ \vdots \\ \sum_{z_{1Pi}} y_i \\ \vdots \\ \sum_{z_{1Ni}} y_i \end{bmatrix}$$

$$S_{2y} = \begin{bmatrix} \sum_{z_{21i}} y_i \\ \vdots \\ \sum_{z_{2Ni}} y_i \\ \vdots \\ \sum_{z_{2Ni}} y_i \\ \vdots \\ \sum_{z_{2Ni}} y_i \end{bmatrix}$$

$$\vdots$$

$$S_{Ny} = \begin{bmatrix} \sum_{z_{2Ni}} y_i \\ \vdots \\ \sum_{z_{NPi}} y_i \\ \vdots \\ \sum_{z_{NPi}} y_i \end{bmatrix}$$

$$\vdots$$

$$\sum_{z_{NPi}} y_i$$

$$\vdots$$

$$\sum_{z_{NPi}} y_i$$

$$\vdots$$

$$\sum_{z_{NPi}} y_i$$

$$\vdots$$

$$\sum_{z_{NPi}} y_i$$

Once the matrix solution given by equation (27) has been determined the intercept A_0 of the fitted model expression may be calculated as

$$A_{0} = \overline{Y} - (b_{11}\overline{Z}_{1} + b_{12}\overline{Z}_{1}^{2} + \dots + b_{1P}\overline{Z}_{1}^{P} + c_{12}\overline{Z}_{1}\overline{Z}_{2} + c_{13}\overline{Z}_{1}\overline{Z}_{3} + \dots + c_{1N}\overline{Z}_{1}\overline{Z}_{N})$$

$$- (b_{21}\overline{Z}_{2} + b_{22}\overline{Z}_{2}^{2} + \dots + b_{2P}\overline{Z}_{2}^{P} + c_{23}\overline{Z}_{2}\overline{Z}_{3} + c_{24}\overline{Z}_{2}\overline{Z}_{4} + \dots + c_{2N}\overline{Z}_{2}\overline{Z}_{n})$$

$$- \dots - (b_{N1} + b_{N2}\overline{Z}_{N}^{2} + \dots + b_{NP}\overline{Z}_{N}^{P} + c_{N-1,N}\overline{Z}_{N-1}\overline{Z}_{N})$$
(32)

C. Comments

The solution developed for evaluating multiple variable regression for Pth degree polynomials with linear cross products is similar to that developed in Section II for the case without cross products. However, in this case, the nested matrices contain additional terms to account for the cross products and hence it is required that $n \ge NP + \frac{N!}{2(N-2)!}$, which again indicates that the number of data points n must be equal to or greater than the number of unknown parameters in the model equation.

As discussed in Appendix B, a computer program has been developed to treat this case. It should be noted that while contrived problems have yielded excellent results, experience with several sets of physical data have generally yielded poorer results. This is evidently due to the larger matrices being manipulated and due to unknowns as to whether true linear cross coupling exists in the given physical process.

IV. SIGNIFICANCE OF THE ESTIMATED REGRESSION EQUATIONS

A. Introduction

To determine if the fitted regression equation obtained from the solution matrix is indeed a useful representation of the input data, it is desirable that certain diagnostics be evaluated. To this end the computer programs discussed in Appendix A and Appendix B determine the standard deviation of the observed data with respect to the fitted equation, the multiple correlation coefficient, and the F statistic as well as the average error and the maximum error of the observed data with respect to the fitted result.

Using these parameters, it is possible to assess the usefulness of the fitted expression for each given application.

B. Analysis of Variance

The significance of the estimated regression equation can be considered from the viewpoint of an analysis of variance as summarized in Table 1, where the total sum of squares is resolved into a component measuring the residual fitting error, and a component which measures the regression variation being tested.

TABLE 1. ANALYSIS OF VARIANCE (WITH AND WITHOUT CROSS PRODUCTS)

A. Analysis of Variance (without Cross Products)

Degrees of Freedom	Type Variation	Sum of Squares (SS)	Mean Square (MS)	F Value
n-1	Total	$S_{yy} = \sum (Y_i - Y)^2$		
NP-1	Residual	$S(RES) = \sum (Y_i - Y_i^c)^2$	$M(RES) = \frac{S(RES)}{NP-1}$	
n-NP	Regression	$S(REG) = \sum (Y_i^c - \vec{Y})^2$	$M(REG) = \frac{S(REG)}{n-NP}$	$\frac{M(REG)}{M(RES)}$

B. Analysis of Variance (with Cross Products)

Degrees of Freedom	Type Variation	Sum of Squares (SS)	Mean Square (MS)	F Value
	Total	$S_{yy} = \sum (Y_i - Y)^2$		
K-1	Residual	$S(RES) = \sum_{i} (Y_i - Y_i^c)^2$	$M(RES) = \frac{S(REG)}{k-1}$	
n-k	Regression	$S(REG) = \sum_{i} (Y_i^c - Y)^2$	$M(REG) = \frac{S(RES)}{n-k}$	M(REG) M(RES)

where MS = SS/degrees of freedom

$$S_{yy} = S(RES) + S(REG)$$

 \overline{Y} = average of observed values

$$k = NP + (N-1) + (N-2) + ... + 1$$

C. Interpretation Diagnostics

As noted by Smille [3], the results of such an analysis of variance can be used to test the combined effect of all of the independent variables on the dependent variable. That is, the hypothesis that all of the population regression coefficients in the model regression equation are zero can be tested since the ratios of the regression mean square to the residual mean square are distributed in an F distribution as shown below:

$$F = \frac{S(REG)/Regression degrees of freedom}{S(RES)/Residual degrees of freedom}$$
(33)

where it is assumed that the observations are selected at random-from a normally distributed population with zero mean and constant variance, that Z_1 , Z_2 , ... Z_N are independent variables following χ^2 distributions, and that only random errors are associated with the observations.

The F ratio calculated from equation (33) can be used to test the statistical significance of the regression equation under consideration by comparing it with the appropriate F_{TABLE} value at the desired probability level with the specified numerator and denominator degrees of freedom; that is, the following test of the null hypothesis may be performed:

$$H_0$$
: $b_{10} = b_{12} = \dots b_{NP} = 0$ accept when $F_c > F_{TABLE}$ (34) reject when $F_c < F_{TABLE}$

D. Output Data

The desired coefficients of the model equation are outputted in E notation where A_0 is the computed intercept of the fitted polynomial expression and the B coefficients are printed out in ascending order of degree with the first P coefficients indicating b coefficients of the first independent variable, the second set of P coefficients indicating the b coefficient of the second independent variable, etc.

Also included in the output data are the number of independent variables N, the degree of the model equation P, and the number of input data points (sets) n. Further, the significance of the estimated regression equation is indicated by the standard deviation, the multiple correlation coefficient, the F ratio, the maximum percent error, and the average percent error.

The values of the dependent variable are also shown for the input data and for the computed values obtained from the fitted expression for each set of data input, as well as the residual difference in the input values and the computed values.

When called for, plotted results can also be obtained which compare the input and computed dependent variables as ordinates to the point interval along the abscissa (which is normally one of the physical independent variables, but which can be a unit indication of each data set in order of input to program). All computed points are connected by straight lines and are plotted with * symbols. The input points are plotted with + symbols and the points are not connected with lines.

Another useful parameter in testing the significance of the regression equation is the standard deviation which is estimated by:

$$s = \left[\frac{\sum_{i} (Y_{i} - Y_{i}^{c})^{2}}{\text{Regression degrees of freedom} - 1}\right]^{\frac{1}{2}} = \left[\frac{S(RES)}{\text{Regression degrees of freedom} - 1}\right]^{\frac{1}{2}}$$
(35)

This result stems from the work of Junkin [4].

Earlier, the analysis of variance technique was used to test the combined effect of the independent variables on the dependent variable using the F statistic. A closely related statistic is the multiple correlation coefficient. R. Smille [3] defines this statistic as the simple correlation coefficient between the observed values of the dependent variable and those estimated by the multiple regression function as given by:

$$R = \frac{S(REG)}{S_{VV}}^{\frac{1}{2}}$$
 (36)

If the observed and estimated values are completely unrelated, R will be zero and, if they are identical the multiple correlation coefficient will be unity. Values in between these limits represent different degrees of correlation or the closeness within which the regression equation describes the original data.

Also of interest is the average of the absolute values of the percent error of the dependent variable, considering each fitted observation:

$$\left| \epsilon \right|_{AVG} = \frac{1}{n} \sum \left| \frac{Y_i - Y_i^c}{Y_i} \right| \times 100$$

During this calculation the maximum absolute error condition can be determined for evaluation purposes.

V. SUMMARY

A powerful multiple regression technique for Pth degree polynomials with and without linear cross products has been developed with which the nonlinear behavior of identified independent variables can be related to a given dependent variable. The polynomial expression can be of the Pth degree and can incorporate N independent variables. The resulting surface fit can be used to summarize trends for a given phenomenon and the analytic results provide a mathematical basis for subsequent analysis.

It is required in the application of this technique that the S matrix be nonsingular and that the input data are reasonably well behaved. It is also required that the number of data points being fitted be equal to or greater than the number of unknown parameters in the model equation.

Two computer programs have been developed to implement this technique for the cases with and without linear cross products. These programs perform matrix operations in double precision and evaluate the various unknown constants in the model regression equation as well as the standard deviation, the multiple regression coefficient, the F statistic, the maximum absolute percent error, and the average of the absolute values of the percent error. Further included in these programs is the solution for the identity matrix to identify any problems in the original matrix inversion process and a means of obtaining machine plots, comparing the computer results to each set of input data.

Studies of many sets of physical data using the technique without cross products have generally yielded excellent results. However, much less experience has been obtained using the program with cross products, although test programs have shown very good correlation. It is, therefore, felt that the technique developed herein can be highly useful to many fields of endeavor.

APPENDIX A

MULTIPLE REGRESSION PROGRAM FOR CASE WITHOUT CROSS PRODUCTS

A. Input Data

The regression subroutine is called with the following statement:

CALL REGRES(Z,YO,LN,N,IP)

where:

Z is a two-dimensional array containing the independent variables used. The first subscript denotes the independent variable and the second subscript denotes the data set.

YO is an array containing the dependent variables which correspond to the independent variables.

LN is the number of data sets.

N is the number of independent variables used.

IP is the degree of the polynomial curve fit.

These arguments must be assigned a value in a driver program.

The regression subroutine incorporates several special routines: RDWT, IOWR, INVRT, and DMATML.

RDWT is a general FORTRAN I/O package which is capable of reading and/or writing on magnetic tape or drum in FORTRAN or non-FORTRAN format.

IOWR is an assembly language I/O routine called by RDWT.

INVRT is a double precision matrix inversion and simultaneous equation solver. The call to this routine is:

CALL INVRT(A,N,M,DETER)

where:

A is the input matrix for inversion or augmented matrix for simultaneous equations.

N is the order of the coefficient matrix.

M=0 for inversion only; otherwise, M is the number of constant vectors.

DETER is the determinant of the coefficient matrix.

DMATML is a double precision matrix multiplication routine with transpose options. The call to this routine is:

CALL DMATML(C,A,B,M,N,K)

where:

C is the product of matrix A times matrix B,

A is the first input matrix,

B is the second input matrix,

M is the number of rows of A,

N is the number of rows of B, and

K is the number of columns of B.

Certain variables have dimension changes that vary depending on the number of data points (LN), the number of independent variables (N), and the degree of the polynomial curve fit (IP). These will be dimensioned as follows:

DSN(NIP2), DSHAT(NIP,1), DB(NIP,1), Y(LN), RESID(LN), Z(N,LN), SHAT(NIP,NIP), ZBAR(N,IP), YO(LN), BZ(LN), B(N,IP), SVHAT(NIP,1), SH(NIP,NIP), XX(LN), PMAX(LN)

where:

LN,N,IP are as defined above and NIP is computed as: NIP = N*IP; NIP2 is NIP raised to the second power.

SMALLZ, SMALZ1, and SMALZ2 should be dimensioned greater than the number of data points and the dimension is set in a PARAMETER statement; for example:

B. Program

In order to run this program on the UNIVAC 1108, the deck is set up as follows:

@RUN,//T JBNAME,320590,VDARBYBIN406, 01, 100

@ASG,T 10,F/1/POS/2

@FOR,IS MAIN, MAIN

(Source deck for inputting data)

@FOR,IS REGRES, REGRES

(Source deck)

@FOR,IS RDWT, RDWT

(Source deck)

@ASM,IS IOWR, IOWR

(Source deck)

@FOR,IS INVRT, INVRT

(source deck)

@FOR,IS DMATML, DMATML

(Source deck)

@MAP,I AA, AA

LIB SYS\$*MSFC \$.

@XOT AA

(Input data)

@FIN

as illustrated in Figure 1.

A complete program listing for the case without cross products is shown in Table 2 and a flow chart indicating the operation of this computer program is indicated in Figure 2.

C. Output Data

The desired coefficients of the model equation are outputted in E notation where AO is the computed intercept of the fitted polynomial expression and the B coefficients are printed out in ascending order of degree (P) with the first P coefficients indicating the b coefficients of the first independent variable, the second set of P coefficients indicating the b coefficients of the second independent variable, etc.

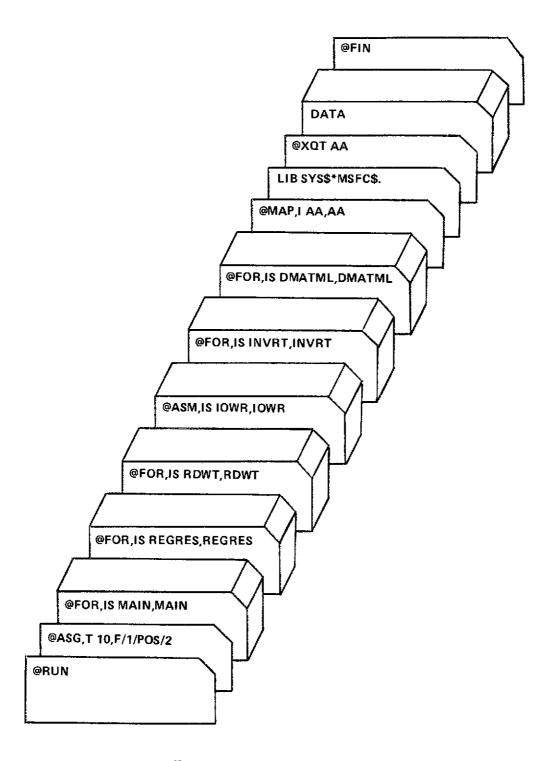


Figure 1. Program deck sequence.

TABLE 2. PROGRAM LISTING (WITHOUT CROSS PRODUCTS)

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TABLE 2. (Continued)

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TABLE 2. (Continued)

EXTERNAL REFERENCES (BLOCK, HAME) DODD 10ENT	2001110-1	INE REGRES	ENTE	er rain	т СО124а			**						
DECOJ 1DENT COUS 1NVH COUS 1NVH	*													
DEST DEST	STURAGE	05£0: COLE	(1),00	3101 0	ATA(0) G	@1662; BL.	ANK . COH	10 N (2) U	00000					
DEBST TORKER COUST C														
OCU COLOR	EXTERBA	L REFERENCE	.5 (BLO	K. HAN	E)									
COUS INWELL COLG DRAFIE COUR OUTSILE COLG CHARDS COLF RIGES COLF R		47 1												
COLID Chaude Colid Chaude Colid Co		-			•									
Cold Chause Cold Chause Cold Col									,					
0012 NEAPS 0014 SORT 0015 NIUTS 0016 NEAPS 0017 SORT 0018 NEAPS 0018 SORT 0018 NIUTS 0018 NEAPS 0019 COUNTY	Colo	Chouse							-		1			
STURAGE ASSIGNMENT LOUDE COUNTY LOCATION, NAME)		_		-										
Cold Colse														
STONAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME) OCUU COISGI ICCOFF LCOU CC147C 10CODF CDDD 001541 10CO3F 0000 001552 10C21F 0001 000075 137G 0001 CC0126 1566 0001 CC0127 173G 0001 0C0144 2066 0001 0C0142 1556 0001 0C0150 214G 0001 CC0126 1566 0001 0C0150 214G 0001 CC0126 1566 0001 CC0127 173G 0001 0C0144 2066 0001 0C0144 214G 0001 0C0150 214G 0001 CC0215 227G 0C01 0C0217 232G 0001 000222 235G 0000 0D1476 24F-0001 CC0225 227G 0C01 0C0217 232G 0001 000222 235G 0000 0D1476 24F-0001 0C0242 250G 0001 0C0250 274G 0001 0C02		MIUIS												
02dd 0015e) 100n	0610	NEHR3%												
Color Colo	STURAGE	_ ASSIGNMENT	T (ULO	CK, TYE	PE. RELAT	TIVE LOCAT	10N, N	(HE)						
0301 C00123 1666 C01 CCC127 173G C001 0C0144 266G 0001 000146 211G 0001 C00150 214G 0001 C00274 252G 0001 0C0272 2222F 0001 0C0272 227G 0001 0C0272 235G 0000 000222 235G 0000 0001476 24F-0001 000274 253G 0001 000423 317G 0001 000451 330G 0001 000422 314G 0001 000423 317G 0001 000451 330G 0001 000451 37G 0001 000451 37G 0001 000451 37G 0001 000574 37G 0001 000574 37G 0001 000574 37G 0001 000574 31G 0001 000574 44G 0001 000663 417G 0001 000574 37G 0001 000574 31G 0001 000574 44G 0001 001044 46C6 0001 00100 53G 0001 001101 505G 0001 001001 001101 505G 0001 001001 001001 001001 505G 0001 001001 001001 001001 001001 001001														
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Cold	0001 0001	0060/6 14 ² 00012 ³ 166	ξ1, 6 G	6501 6001	CC0106	1506 1736	0000	001531 000144	1500F 266G	1000	000112	1556 2116	0001	- 000113 160 000150 214
Count CC-470 4476 CG CC55C 3434 CG CG CG53Z 25CG CG CG CG CG CG CG CG	0301 0301 -8406	0060/6 144 600123 166 901522 223	či, 66 22F	0001 0001	000104 000127 000215	1506 1736 2276 -	0001 0001 0000	001531 000144 000217	1500F 2066 2326	0001 0001 - 0001	000112 000146 000222	1556 2116 2356	0001 0001 - 0000	- 000113 160 000150 214 - 001476 24F
DULI CODOLO 3776 CCC1 CCC41 4C24 COC1 D0C633 4146 COD1 D0C635 4176 OUDI CDC637 4226 CCC1 CUC41 CUC677 4316 CQUI CCC725 4446 COC1 D0L044 40C6 D0C1 D0L100 5036 CDC01 D0L105 5036 CDC01 D0L107 526 CDC01 D0L107 526 CDC01 D0L107 5466 OUDO CDC637 4226 CDC01 D0L107 5466 OUDO CDC637 5467 5467 5467 5467 5467 5467 5467 546	0001 0001 0000 0001	000076 142 000123 166 001522 222 000264 256	ki, 60 22F	0001 0001 0005	CCC104 CCC127 CCC215 CC1526	1506 1736 2276 2500F	0000 0001 0001 0000	001531 000144 000217 001537	1500F 2666 2326 2502F	0001 0001 - 0001 0001	000112 000145 000222 000274	1556 2116 2356 2536	0001 0001 - 0000	- 000113 160 000150 214 - 001476 24F 000320 261
Cold	1000 1000 1000 1000 1660	000076 142 000123 166 001522 222 000264 250 000339 266	21, 22F 2G	0001 0001 0001 0001	CC0104 CCC127 CCC215 CC1526 CC0350	1506 1736 2276 2500F 2716	0001 0001 0001 0000	001531 800149 800217 001537 000422	1500F 2g6G 2326 2502F 314G	0001 0001 - (001 0001	000112 000146 000222 000274 000423	1556 2116 2356 2536 3176	0001 - 0000 - 0000 - 0001	- 000113 160 000150 214 - 001476 24F 000320 261 - 000451 330
Coli	0304 0301 -8400 0201 0381 0381	000076 144 000123 164 001522 223 000264 254 000339 264 000370 443	21, 66 22F 16 16	0001 0001 0001 0001	CCC164 CCC127 CCG215 CC1526 CC0350 CCC5CC	1506 1736 2276 2500F 2716 3434	0001 0001 0000 0001 0000	001531 8C0144 660217 061537 000422 000532	1500F 2066 2326 2502F 3146 3506	0001 0001 - 0001 0001 0001	000112 000146 000222 000274 000423 000567	1556 2116 2356 2536 3176 3646	0001 0001 0001 0001	- 000113 160 000150 214 001476 24F 000320 261 000451 330 000570 367
0500 K C31466 AMAX	0301 0301 0301 0400 1400 1400	000076 144 000123 166 001522 222 000264 256 000339 26 000470 443 000610 37	21, 66 22F 26 76	6501 6601 6601 6601 6601 6601	CC0104 CC0127 CC0215 CC1526 CC0350 CC050C CC0411	1966 1736 2276 2900F 2716 3434 4026	0001 0001 0001 0001 0001	001531 000144 000217 001537 000422 000532	1500F 2066 2326 2502F 3146 3506 4146	6001 6001 - (001 6001 6001 6801	000112 000146 000222 000274 000423 000567	1556 2116 2356 2536 3176 3646 4176	0001 0001 0001 0001 0001	- 000113 160 000150 214 001476 24F 000320 261 000451 330 000570 367 000637 422
0000 D 000136 021ER (CCC D 000272 DSMAT CCCC D 000276 DSM 0000 R 001371 FLDX 0000 R 001405 FLDY 0000 L 001446 FRATIO 0000 1 EC1421 L 0000 L 001452 LCL 0000 L 001445 LCD 0000 L 001447 LRON 0000 L 001447 LRON 0000 L 001447 LRON 0000 L 001447 LRON 0000 L 001440 LDL 0000 L 001440 LDL 0000 L 001440 LDL 0000 L 001447 LRON 0000 L 001447 L 0000 L 001440 LL 0000 L 001447 L	0301 0301 0301 0400 1400 1400 1400	000076 144 000120 166 001522 223 000264 256 000339 263 000470 443 000610 373 000667 433	21, 66, 22, 76, 76, 76,	6001 6001 6001 6001 6001 6001	CCC104 CCC127 CCG215 CC1526 CCU350 CCC5FC CCC411 CCC725	1566 1736 2276 2560F 2716 3434 4626 4446	0001 0001 0001 0001 0001 0001	001531 00144 000217 001537 000422 000532 000633	1500F 2046 2326 2502F 3146 3506 4146 4606	6001 6001 - (001 6001 6001 6801 0001	000112 000145 000222 000274 000423 000567 000635	1556 2116 2356 2536 3176 3646 4176 5036	0001 0001 0001 0001 0001 0001	- 000113 160 000150 214 - 001476 24F 000320 261 - 000451 330 000570 367 000637 422 001101 505
DOUG & GG1446 FANTIO COO I CT1421 I COOD I GG1452 ICL GG00 I GG1445 ICDL OUGQ I OD1443 IERR GGG0 I GG1446 IR GG00 I DG1444 IRON ODDO I GG1447 IRON	5301 5301 5301 5201 5201 5301 5301 5301	000076 144 000123 166 001522 222 000264 256 000339 266 000319 37 000667 43 001175 561	21, 22, 5 25, 5 26, 7 3, 6 4, 6 4, 6 4, 6 4, 6 4, 6 4, 6 4, 6 4	0001 0001 (000 0001 0001 0001 0001 (001	CCC104 CCC127 CCC215 CC1526 CC0350 CCC5CC CCC411 CCC725	1506 1736 2276 2500F 2716 3436 4626 4446 5216	6061 6061 6061 6061 660 6001 6001	001531 00144 000217 001537 000422 000532 000633 001004 051145	1500F 2066 2326 2502F 3146 3506 4146 4606 E366	6001 6001 6001 6001 6001 6801 6001	000112 000146 000222 000274 000423 000567 000635 001100	155G 211G 235G 253G 317G 364G 417G 503G	0001 - 0000 0001 0001 0001 0001 0001	- 000113 160 000150 214 001476 24F 000451 330 000570 367 000637 422 001101 505 001331 ADA
0000 1 001440 1	0301 0301 0301 0301 0301 0301 0301 0301	000076 144 000123 166 001522 222 000264 25 000339 26 000470 34 000667 37 000667 37 001475 50	20, 20, 20, 20, 30, 30, 40, 40, 40, 40, 40, 40, 40, 40, 40, 4	6001 6003 6003 6004 6004 6001 6001 6001	CCC104 CCC127 CCG215 CC1526 CCG350 CCC5CC CCC4125 CCC1227 CCC1466	1506 1736 2276 2500F 2716 3434 4626 4446 5216	0001 0001 0001 0001 0001 0001	001531 000144 000217 001537 000422 000533 001034 001145	1500F 2066 2326 2502F 3146 3506 4146 4606 5366	GOOL GOOL COOL COOL GOOL GOOL GOOL GOOL	000112 000146 000222 000274 000423 000567 000635 001167	155G 211G 235G 253G 317G 364G 417G 503G 5446G	0001 - 0000 - 0000 - 0001 0001 0001 0001	- 000113 160 000150 214 0001476 241 000451 330 000570 367 000637 422 001101 505 R 001331 ADA D 000264 DB
0900 1 C01440 10N[T	0304 0304 0304 0304 0304 0304 0304 0304	000076 192 000123 166 001522 225 000254 265 000254 265 000254 265 000470 345 000470 375 000677 435 001175 665 000106 065	Zh Barte Zer Ger Ger Ger Ger Ger Ger Ger Ger Ger G	6501 6001 6001 6001 6001 6001 6001 6000 6000 6000 6000 6000	CC01e4 CC0127 eC6215 CC1526 CC055C CCC511 CC0725 CC0127 CC0127	1506 1736 2276 2500F 2716 3434 4026 4446 5216 5216 555447	CCOC (CCOC) (CCOC) (CCC)	001531 8C0144 660217 061537 060422 6C0532 66C633 0611045 4 003544	1500F 206G 232G 2502F 314G 350G 414G 460G E36G 6	GOOL GOOL COOL GOOL GOOL GOOL GOOL GOOL	000112 000146 000222 000423 000423 000635 001167 000632	1556 2116 2356 	0001 - 0000 - 0000 - 0001 - 0001 - 0001 - 0000 F	- 000113 160 000150 214 001476 24F 070320 261 000451 330 000570 36 000570 37 000637 422 001101 505 001331 ADA 000264 DB R 001405 FLD
	0301 0301 0301 0301 0301 0301 0301 0300 000 00	000076 144 000123 164 001523 25 000339 26 000339 26 000339 36 00047 37 00047 43 001175 50 000146 Add	Zh Barte Zer Ger Ger Ger Ger Ger Ger Ger Ger Ger G	COUL COUL COUL COUL COUL COUL COUL COUL	CC01e4 CC0127 eCG215 CC01526 CC0356 CC055C CC0411 CC0725 CC01127 CC01127 CC01127 CC01127	1506 1736 2276 2500F 2716 3434 4026 4446 5216 AQ DSHAT	C000 C001 C001 C001 C001 C001 C001 C001	001531 800144 900217 901537 904422 902532 906633 901994 901145 9003444	1500F 2046 2326 2502F 3146 3506 4146 4606 E366 B	GOOL GOOL COOL GOOL GOOL GOOL GOOL GOOL	000112 000146 000222 000274 000423 000567 000635 001100 001167 001632 001371	1556 2116 2356 2536 3176 3476 4176 5036 5466 82 FLDX	0001 - 0000 0001 - 0001 0001 0001 000	- 000113 160 000150 214 - 001476 24F 010451 330 000570 367 000637 367 00131 40A 000264 05 001405 FLD
0000 1 001430 NR	0301 0301 0300 0201 0301 0301 0301 0300 0300	000076 144 000123 164 001523 25 001523 25 000254 25 000259 26 00010 37 000667 43 000105 60 000105 60 000105 60 000105 60	2,, 6G 22F 2G 7G 7G 1G 7G 1G 7G 1G 7G 1G 7G 7G 7G 7G 7G 7G 7G 7G 7G 7G 7G 7G 7G	0001 0001 0001 0001 0001 0001 0001 000	CC0106 CC0127 CC0215 CC01526 CC03550 CC057C CC01127 R G01464 D 002402 I CC1611	1506 1736 2276 22500F 2716 3434 4626 4446 5216 AO DSHAT 1NUPS	0000 0001 0001 0001 0001 0001 0001 000	001531 8C0144 860217 8C1537 8C1537 8C0532 8C0532 8C0533 8C1145 8C01145 8C01454	1500F 2046 2326 2326 3146 3506 4146 4606 5366 605N 1CL	6001 6001 - (003 6001 6001 6001 6001 0001 0000 H	000112 000146 000222 000274 000423 000567 000635 001100 001167 000637 001371 001371	155G 211G 235G 235G 317G 364G 417G 503G 546G 62 FLOX 1ROn	0001 0000 0001 0001 0001 0001 000	- 000113 160 - 000150 24F - 001476 24F - 01320 261 - 000451 330 - 000570 367 - 000677 422 - 031101 505 - 001331 ADA - 001244 DB - 001445 FLD - 001442 IER
0000 R 001435 PRAX COCC R CCC372 RESID DOCC R 001457 RHAT 0000 R 001434 RR 0000 R 001476 SH 0000 R 001435 RHAT 0000 R 001435 SHES 0000 R 001435 STALLZ 0000 R 001032 SHALZZ 0000 R 001435 SHES 0000 R 001435 STALLZ 0000 R 001435 SYHAT 0000 R 001436 STALLZ 0000 R 001436 SYHAT 0000 R 001436 SYHAT 0000 R 001436 SYHAT 0000 R 001436 SYHAT 0000 R 001435	0301 0301 0301 0301 0301 0301 0301 0300 0300 0300 0300 0300	000076 144 000123 164 0011523 223 001254 255 0002339 265 0002339 265 000470 437 000667 433 001175 501 000306 065 000460 FA	2, 6G 22F 2G 7G 7G 1G 7G 1G 	COUL COUL COUL COUL COUL COUL COUL COUL	CC01e6 CC0127 eC6215 CC1526 CC055C CC055C CC01127 K C011429 B UUX02 I CT1421 CC11411	1506 1736 2276 2500F 2716 3434 4026 4446 5216 005HAT 1 1NJPS	0000 0001 0001 0001 0001 0001 0001 000	001531 900149 900217 901537 903422 906532 906633 91194 9011454 9011452 1 901452	1500F 2046 2326 2322 3146 3506 4506 4506 5366 605N 1CL 18	0001 0001 - 0001 0001 0001 0001 0001 000	000112 000146 000222 000474 000423 000635 001100 001167 000632 001371 001444 001431	155G 211G 235G 253G 317G 364G 417G 503G 546G FLOX ICOL 180n K	0001 0000 0001 0001 0001 0001 000	- 000113 160 000150 214 001476 24F 010320 261 000451 330 000570 37 000637 422 001101 505 001331 ADA 000264 ADA 001405 FLD 1 001443 IER 1 001447 L
0000 R 001032 SHALZ 0000 R 001435 SHELZ 0000 R 001032 SHALZ 0000 R 001435 SHEC 0000 R 001437 SHES 0000 R 001456 STADEV 0000 R 001464 SUN 0000 R 001455 SYHAT 0000 R 001436 SYY 0000 R 001423 X 0000 R 001424 XB 0000 R 001317 XX 0000 R 000310 Y 0000 R 001425 YB	0301 0301 0301 0301 0301 0301 0301 0300 000 00	000076 144 000123 164 000123 124 000124 25 000239 26 000339 26 00047 37 000147 5 50 000146 00 000146 00 000146 10 000146 10	Zi, bc ZZF TG TG TG TG TG TG TG TG TG TG TG TG TG	6861 6961 6961 6961 6661 6661 6660 6660 66	CC0106 CC0127 CC0215 CC0356 CC0356 CC055C CC0411 CC0725 CC01127 R G01465 CC1421 CC1421 CC1611 CC1451 CC1451	1506 1736 2276 2500F 2716 3434 4426 4446 5216 AO DSMAT 1 NJPS L1	0001 0001 0001 0001 0001 0001 0001 000	001531 8C0147 061537 061537 060422 060533 061004 061145 40 00060 1 061454 1 061454 1 061454	1500F 206G 232G 232ZF 314G 450G 414G 460G 536G 60SN 1CL LR	0001 0001 0001 0001 0001 0001 0001 000	000112 000146 000222 000423 000423 000635 001100 001167 000632 001371 001445 0014445	155G 211G 235G 235G 317G 364G 417G 503G 546G 62 FLDX ICOL IKON K	0001 0000 0000 f	- 000113 160 000150 214 - 001476 24F - 070320 261 - 000451 330 - 000570 367 - 030637 422 - 031101 505 - 001431 ADA - 001405 FLD - 1 001442 156 - 1 001442 156 - 1 001427 NIF
0000 R 001437 SRES 0000 R 001456 STADEY 0000 R 001464 SUN 0000 R 000455 SYHAT 0000 R 001436 SYY 0000 R 001436 SYY 0000 R 001434 SYY	10000000000000000000000000000000000000	000076 144 000123 164 000123 25 000239 26 000239 26 000239 37 000407 43 000107 43 000107 60 000107 60	Z, bc 22F 	0001 0001 (0001 (0001 0001 0001 (0001 (0000 0000 0000 0000 0000	CC0106 CC0127 CC0215 CC0255 CC055C CC057C CC01127 R G01464 0 000242 1 CC1451 1 CC1451 1 CC1451 1 CC1454	1506 1736 2276 2276 2500F 2716 3434 4026 4026 4046 5216 AO DSHAT 1 NUPS 12 L1	0001 0001 0001 0001 0001 0001 0001 000	001531 000149 000217 001537 000422 000532 000633 001104 0011145 000000 1 001452 1 001454 1 001454	1500F 206G 232G 232ZF 314G 350G 414G 460G E36G E 05N 1CL 1R J	0001 0001 0001 0001 0001 0001 0001 000	000112 000146 000222 000474 000423 000567 000635 001167 000637 000637 001371 001445 001444 001431	155G 211G 235G 235G 317G 364G 417G 503G 546G FLDX ICOL IROn K	0001 0000 00001 0001 0001 0001 00	- 000113 160 000150 214 - 001476 24F 000451 330 000570 367 000637 367 000637 367 001331 ADA 0 000264 DB 0 001443 IER 1 001447 L 1 001447 L 1 001467 MER
100 x 001423 x. CG00 x 001424 xs CG00 k 001317 xx 0000 x 000310 Y 0000 x 001425 YB	0301 0301 0301 0301 0301 0301 0301 0301	000076 142 000123 164 000123 22 000234 25 000239 26 000239 26 000239 26 0002470 37 00047 43 000246 06 000246 06 000246 16 000246 16 0002	2, 6 c c c c c c c c c c c c c c c c c c	0001 0001 (0001 (0001 0001 0001 0001 00	CC0127 CC0127 CC0215 CC01526 CC055C CC055C CC0725 CC0127 CC01127	1506 1736 2276 2500F 2716 3434 4526 4446 5216 AQ DSMAT 1 1NJPS 12 L1 MSECT RESID	0001 0001 0001 0001 0001 0001 0001 000	001531 8C0144 600217 001537 000422 000533 001004 001145 0003644 0011454 1 001454 1 001454 1 001454 1 001454	1500F 2046 2326 2322 3146 3506 4006 2346 605N 1CL LR L2 NHDS NHAT	GOOL GOOL GOOL GOOL GOOL GOOL GOOL GOOL	000112 000145 000224 000224 000423 0005635 001100 001167 000632 001371 001445 001444 001431 001444 001434	155G 211G 235G 2253G 317G 364G 417G 503G 546G FLDX ICOL IKON K H	0001 0000 -	- 000113 160 000150 24F 001476 24F 010476 24F 010320 261 000570 37 000570 37 001331 ADA 001331 ADA 001405 FLD 1 001442 ISE 1 001447 L 1 001447 L 1 001447 L 1 001447 K R 001167 FE R 001167 SH
	1000 1000 1000 1000 1000 1000 1000 100	000000 144 000123 164 000123 124 000124 25 0002339 26 0002339 26 000339 26 000339 26 000339 26 000349 51 0001490 FA 0001490 IV	21, 66, 76, 76, 16, 16, 16, 17, 17, 17, 17, 17, 17, 17, 17, 17, 17	0001 0001 0001 0001 0001 0001 0001 000	CC0126 CC0127 CC0215 CC0356 CC0356 CC0356 CC0127 CC0127 CC01421 CC1421 CC1421 CC1441 CC1441 CC1441 CC1441 CC1441 CC1441 CC1441 CC1441 CC1441 CC1441	1506 1736 2276 2276 2500F 2716 3434 4026 40446 5216 AO DSHAT 1 INJPS 12 L1 HSECT RESTD SHALLZ	0000 0000 0000 0000 0000 0001 0001 000	001531 8C0144 6C0217 001537 00422 0C0532 0C0533 001004 001145 0010454 001454 1 001454 1 001454 1 001454 1 001454	1500F 2046 2326 2322f 3146 3506 4506 505N 1CL 1R 1L2 NBDS KHAAT SMALZ1	GOOL GOOL GOOL GOOL GOOL GOOL GOOL GOOL	000112 000146 000222 000274 000423 000563 001100 001167 001463 001444 001444 0014431 0014431	155G 211G 235G 235G 317G 364G 417G 503G 546G 82 FLOX ICOL IKON K H PERAYG RR SHALZ2	0001 0000 0001 0001 0001 0001 000	- 000113 160 000150 214 001476 24F 010320 261 000451 330 000570 37 422 031101 505 001331 APA 000264 DB 1 001443 IER 1 001447 L I 001467 NIF R 001467 5H R 001467 5H R 001476 5H R 001475 SHR
	0301 0301 0301 0301 0301 0301 0300 0300	000076 144 000123 164 000123 25 000239 26 000239 26 000239 26 00030 37 000140 54 00030 54 00030 54 1 00030 64 1 00030 64 1 001440 64 1 001430 64 1 001430 64 1 001430 64 1 001437 64 1 001437 54	in the second se	0001 0001 0001 0001 0001 0001 0001 000	CC0106 CC0127 CC0215 CC0356 CC0356 CC055C CC01127 CC01127 CC01127 CC01127 CC01127 CC011461 CC11451 CC11451 CC11451 CC11451 CC11451 CC0322 CC0322 CC0324 CC03	1506 1736 2276 2276 2500F 2716 3434 4446 5216 AO DSHAT INJPS 12 L1 HSECT RESID SHALLZ STALLZ	0001 0001 0001 0001 0001 0001 0000 0000 0000 0000 0000 0000 0000 0000	001531 00147 001537 001537 000422 009532 009533 001145 001145 001454 001454 1 001454 1 001454 1 001454 1 001454 1 001454 1 001454 1 001454 1 001454 1 001454 1 001454	1500F 206G 232G 232ZF 314G 250G 414G 460G E36G B 05N 1CL LR J L2 khds khat 54ALZI 54ALZI 54ALZI	GOOL GOOL GOOL GOOL GOOL GOOL GOOL GOOL	000112 000146 000222 000274 000423 000567 000163 001167 000632 001371 001445 001445 001431 001431 001433 001432	155G 211G 235G 235G 317G 364G 417G 503G 546G 17COL 18COL 18COL 18COL 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	0001 0000 0001 0001 0001 0001 000	- 000113 160 000150 214 - 001476 24F - 001476 24F - 000451 330 - 000570 367 - 001637 367 - 001331 ADA - 001435 FB - 001447 FB - 001447 FB - 001447 FB - 001467 FB - 001475 SB - 001435 SB - 001435 SB - 001435 SB - 001435 SB - 001435 SB - 001435 SB
	6304 9261 6201 6201 6201 6201 6201 6200	000076 142 000123 164 000123 122 201224 25 0002339 26 0002339 26 000339 26 000339 26 000349 61 000449 61 000449 10 000449 11 000449 11 000449 11 000449 11 000449 11 000449 11	Zi, 6G CG	0001 0001 0001 0001 0001 0001 0000 0000 0000 0000 0000 0000 0000 0000	CC0127 CC0127 CC01526 CC01556 CC0556 CC0725 CC01127 CC01127 CC01127 CC011461 CC01461 C	1506 1736 2276 2276 2716 3436 4446 5216 00 05HAT 1 1NJPS 12 L1 145ECT HESELD SHALLZ STALLZ STALLZ	0001 0001 0001 0001 0001 0000 0000 000	001531 8C0144 6C0217 0C1537 0E0422 0C0533 0E1204 0C1145 0 0E04454 0 0E04454 1 0C1454 1 0C1454 1 0C1454 1 0C1454 1 0C1454 1 0C1454 1 0C1454 1 0C1454	1500F 2046 2326 2322F 3146 3506 4606 4606 E366 BOSN ICL LR J LZ WHAT SMALZI SUM	GOOL GOOL GOOL GOOL GOOL GOOL GOOL GOOL	QQU112 QQQ146 QQQ274 QQQ423 QQQ423 QQQ4635 QQ1100 QQ1167 QQQ432 QQ1371 QQ1445 QQ1444 QQ1431 QQ1443 QQ1434 QQ1434 QQ1434 QQ1434 QQ1434 QQ1434	155G 211G 235G 253G 317G 364G 417G 503G 546G FLDX ICOL IRON K H PERAVG RK SHALZ2 SVHAT	0001 0000 0001 0001 0001 0001 000	- 000113 160 000150 214 - 001476 24F - 001476 24F - 000451 330 - 000570 367 - 001637 367 - 001331 ADA - 001435 FB - 001447 FB - 001447 FB - 001447 FB - 001467 FB - 001475 SB - 001435 SB - 001435 SB - 001435 SB - 001435 SB - 001435 SB - 001435 SB

TABLE 2. (Continued)

00101 3 c	PARAMETERS USING REGRESSION TECHNIQUES
00103	- PARAMETER 101 METAL DI METAL
00104 5•	DOUBLE PRECISION DEN(81).DEMAT(9.1).DB(9.1)
CD1U5 0+	DOUBLE PRECISION DETER
Culu6 7•	DIRENSION Y 1301-RESIO(10), Z (3,10), SMALLZ(101H1, SMAT(9,9),
C0106 8*	*ZHAR(3,3), YO(15).BZ(10).B(3.3), SYMAT(9,1),
00106 7.	*SHALZITIDIN', SHALZZ(10]H)
00107**********	SIMENSIUM SH(9,7),XX(1C)
66116 114	DIMENSION ADARY(22)
C_111 12*	OTHERSTON PMAX(12)
C011Z 13+	DIMENSION FLOX((2),FLOY(12)
CS [13 144	DATA FLOY/72H Y VALUES
CC113 15*	•
CG115 16*	DA'A FLDX/72H POINT INTERVALS
00115 1/*	· · · · · · · · · · · · · · · · · · ·
CU117 18+	OATA (ADARY)(), Tel, 3)/6HONE , 6H COPY.6HFLO /
C0121 19*	CALL IDENI(Y, ADAKY)
C0122 20•	NauS=1DIM
C6123 21•	XL ≈ 3 • U
C0124 122*1 7 7 111	X8=11*D
Cu125 23+	Y8=4.0
	YT#12+0
G0127 25*	WEITELG. 100CO) N. IP. LN
	FORMAT(1HL,2HN=14,3X,2HP=14,3X,3HLN=14)
CO135 27* CO136 ** 28* ******	N(P=H+1?
CO141 29=	00 1234 [11]19
	D0 1234 J=1:IP ZBAR(1,J)=0=0
0.147 31+	ZDARTI, 50-04-04-04-04-04-04-04-04-04-04-04-04-04
	SHALL(KHEUSE
05154 334	DO 1236 1=11/kJP
80157 TH 34*	00 1236 J=1;RiP
	SH. T(1,J)=0+0
5(105 30#	00 1257 [althip
E8170 + 37* 1237	\$\\A \t(\;\t)=C.c
US172 3ar	DO 1238 T=1+LN
Co175 39* 1238	η (1 · 1 · 1 · 1 · 1 · 1 · 1 · 1 · 1 · 1
	YPARCEC+G
U&200 91≠	0 • D = U A A B Y
25201 42*	RB=C+C
00202 43•	SAEG=U.S
ug203 44*	SYY#G+E
Ug204 45∓	SHESHO = 0
Cc204 - 46* C	DETERMINE THE SMALL Z VALUES FOR THE ASSUMED MODEL FORM
წე2ე4 4/• (მე2ე5 4≈• ·	and Park And A
C0210 49*	50 225 let,N
Cu213 50*	00 2/25 J=1,1P 00 2/25 K=1,kp
- -	TOAR(1,1)=ZBAR(1,1)=Z(1,K).*J
	29ah(1)/J-2bah(1)/J/bh
Cu223 53+	ZONALI POTENTIA DE LA CONTRACTOR DE LA C
CD224 5++	NSECT*(NaUS*271/28
ruz25 55+	N3601 (1984)
EC226 56*	D0 250 [*1, N
20231 5/*	00 250 J=1,1p
U0234 ·· 58+ ·· = -	DC 245 Xel,LN
* = -	

TABLE 2. (Continued)

	_			•
00237	59		SMALLZ(K)=Z([,K)=+J=Z0AR(],J)	
.00291	: ۱۵ ک ـــ	' 	CALLIORDWR(1,IUNIT:ISECT,SMALLZ,NGOS,IERR)	AMAN HELD. V AND ST. 11 TO ST.
00242	011	250	ISECT * ISECT * NSECT	
Dú242	62			
03242	6.5		COMPUTE SHAT MATRICES FOR USE IN THE LEAST SQUA	HES SOLUTION
CU242	. 64		OF FINDING THE B.S.	
00242	65		• • • • • • • • • • • • • • • • • • • •	
00242			فللماء والمنتسف فالمراكبين ووواله الهاها والماسين والرازي والمنافية	
56245	67		1xC#≠G	
09246	911		[COT=1	
00247	69		DO 455 [K=1+N	
00252	. 75		00 400 L=1,IP	and the second s
00255	71		ISECTATIK-1)+1P*NSECT+(L=1)*NSECT+1	
-	7 Z		"CALL TORNOR(2, TUNIT, ISECT, SMALZI, NWOS, TERR)	
00257	73		IRUX=IROA+1	
00250	74		00 350 J≠I,N	, , , , , , , , , , , , , , , , , , ,
00249	75		pc 350 K=1,1+	
00266	. 70		1SECT=(d+1)*IP=NSECT+(K+1)+NSECT+1	A CALL OF THE PROPERTY OF THE
Cc267	77		CALL IDHDAR 2. IUNIT . ISECT . SMALZZ . NWDS . IEHR)	
	7 ::			
05273	79	. 390	SHATIIROW, ICOLI#SHATIIROW, ICOLI#SHALZI(II#SHALZ	(2(1)
01/274			SHIROW, ICOLI=SHAT(ROM, ICOL)	The second secon
00275	ьl		CONTINUE	
00277	82	-	[F(1CGL.EG.N.1P) 1COL+0	The second secon
C0301	63		[[UL=100L+]	
- 00304	- 64		CONTINUE	
20306	د ه		CONTINUE	
26310	00		NK=1KUY	
06311	87		I 2 = 1	
26312	88		[CL=N=IP	الاستخداد بالمستقيل والالوال
50313	85		DO 1322 1=1+1CL	
20319			- DO 1322 J=1+180%	,
50321	91		05: (12)=SH(J, t)	
00322			1.2=1.2+1	the second secon
00325	6 93		M=S	
C0326	94		CALL INVETTOSMINHIMIDETERS	the second secon
56327	95		00 450 I=1,LN	
	· · · · · · · · · · · · · · ·		484K0=464K0+40(1)	
02334	97		YBARQ=YBARQ/LN	
C0335	9 -		NIP=0+IP+1	
06336	وا پ		IKO##1	
20337	100		00 719 1=1,N	
00342	101		00 710 J=1, LP	
	102		15ECT=(1-1)*1P*NSECT+(J-1)*NSECT+1	
62346	103		CALL IDROWR (2. LUNIT . ISECT, SHALZZ, NWDS, TERR)	
00347	104	•	no 7ag K=1.4N	
06352	10.		SVHAT(180#, 1)=5VHAT11ROW+1)+SMALZ2(K)+(YO(K)=Y)	ARO)
00353	Los		1 DSHAT(IROn, 1) = SVHAT(IRO#+1)	, , , , , , , , , , , , , , , , , , ,
86355	Laz		1 1 1 1 1 1 1 1 1 1	
	Lga		CUMPUTE B'S FOR THE ASSUMED HODEL	
00355	109			•
	- 110		IR+1×04-1	and the second s
02361	111		CALL DMATHE OB DSH DSHAT IN IR. 11	
00362	_		12=1	
00343	113		00 1331 1=1 ·N	
		•	00 1331 J=1+18	

TABLE 2. (Continued)

0n371 ij5•	g(1,J)=0B(1 ² ,t)
00372 116= 1331	-12+12+1
Eg375 117*	AU#TBAHO
00376 1100	D0 23 1=1.N
Ca4a: :: +	DO 23 J=11P
	AD=AD-8([,])*20Ak([,])
C0407 1214	4H17E(6,24) AO
	FONDATIINU, 3HAD=,E[0.7)
00413 123+	00 75u 141,th
00416 1240	00 75c J=1,8
50421 1254	OU 756 Kal, IP
	BZ(1)*BZ(1)*G(J,K)*Z(J,I)**K
D0424 327+ C	BILLI-BILL GOVERNMENT OF THE STATE OF THE ST
C:424: -128# C	COMPUTE THE Y POINTS
20424 129+ G	Child Art The Constitution of the Constitution
00430 \$304	DO 775 1=1,LN
50433 1314	00 7/2 (====================================
	YARRC=YMARC*Y(I)
00435 133+	RESID(1)=Y0(1)-Y(1)
	K4=KK, G=Sig(I) v. E
	CONTINUE
	YDAKC*TBAHC/LN
98441 (37* C	COMPUTE THE STANDARD DEVIATION.
60441 lad C	CONFORCE THE STANDARD DESTRITORS
- 00441 139+ C	D. Carlotta and Carlotta
40	STADEV=SGRT(NR/(LN-N-IP))
CG442 414 C	TO THE WILL THE CORPORATION CONFICENCE BUILT AND
CG442 142 C	COMPUTE THE BULTIPLE CORNELATION COEFFICIENT, MHAT, AND
00442 143 C	THE F RATIO+FRATIC+
00442 1444 C	70 000 F 1 1 1 1
D0443 [45#	po 800 I=1,Ln
Conto Laot	SHEG=5REG+(1(1)-TBARC)++2
05447 147*	SYY*[YQ([I=YBARQ)**2
	SHES#SRES#RESID(1)**2
05452 144+	HHAT-SORTISKEG/SYYI
ζ ₀ 463 l50•	[F(MAT+GT+1+0)] RHAT=2+0TRHAT
00455 151*	FRATIO=(SHEGVIN+1P+1))/(SHESV(LN-N+IP))
CC456 - 152*	XX CE P T = -
00457 133*	DO 83 LI=2.LN
	XX (L[] = X (L[] = 1] + 1 +
80464 155*	L1=1
20965 156*	[2*0] CALL WUIK3LICI, XL, XR, YB, YT, 40, FLDY, FLDY, -LN, XX, Y)
B0966 157*	
20167 158	CALL QUIKSI (L2.XL.XR.YB.YT.34.FLDX,FLDY,LN,XX.YD)
- 00470 - 159* - 03475 - 160* - 1880	WRITE(6,LUGU) STADEV,RHAT,FRATIO FORMAT(1HU,19HSTANDARD DEVIATION=E16.9,4x,33HMULTIPLE CORRELATION
	*COEFFICIENT*E16.9,4%,8HF HATIO*E16.7)
CD176 1624	WRITE(5,222)
	FORMATTINU, B COEFFICIENTS 1
00501 · la4* · · · ·	Wilt-(6-2000) ((B()+U),U=(,1P),I=(,N)
	FURUAT(1H3,5E2):9/)
00513 Las*	##178(\$.150G)
0.5:3 16/4	481/0(6-10023)
	FORMAT(!Hu,lox,ZHTO:t6x,ZHYC,I5X,5HYQ-YC)
13920 169*	Da 2000 1814LN
GG253 [\] 1	#RIT(16.2502) +0(11:4(1).HESIO(1)

501	CONT(NUE		
531	SUM=C. DO SQ1 L=1,LN PMAX(E)=ABS((YO(E)-Y(E))/Y(E) SUM=SUM+PHAX(E) PERAYG=(SUM/EN)*1GC* AMAX=PMAX(I) DU SG5 L=2,LN		
	DO SJ1 L=1, LN PMAX(E)=AUS((YO(E)-Y(E))/Y(E) SUN=SUM+PHAX(E) PERAYG=(SUM/LN)*1GC* AMAX=PMAX(I) DU SJ5 L=2, LN	· · · · · · · · · · · · · · · · · · ·	
	PMAX(E)=A0S((YO(E)-Y(E))/Y(E) SUN=SUN+PHAX(E) PERAYG=(SUM/EN)*1GC* AMAX=PMAX(I* DU 535 L=2,EN	· · · · · · · · · · · · · · · · · · ·	
	SUN=SUN+PHAX(L) PERAYG=(SUM/LN)+1GC+ AMAX=PMAX(1 [‡] DU 5G5 L=2,LN	· · · · · · · · · · · · · · · · · · ·	
	PERAVG=(SUM/LN)+10C+ AMAX=PMAX(17 DU 535 L=2,LN		
	AMAX=PMAX(1) DU SGS L=2,LN		
	po śgś L≡Z,LN		
	IF (AMAX-PHAX(L)) 586,585,585		
ಶಭರ	AMAX#PMAX(L)		
595	CONTINUE		
	PERMAXMAMAX*100*		
	#RITE(8.10021) PERMAX, PERAVG		
19021	FORMATCINO.22HMAXIMUM PERCENT	ERROR"EL6.9.6%, 22HAVERAGE PERCENT	Ł R
ı	PROH=616+91		
	CALL ENDIOR		
	RETURN	•	
	END	The second secon	married and and the discussion of
	19921	#RITE(&.10021) PERMAX,PERAVG 1992) FORMAT()HO,22HMAX1MUM PERCENT *ROH=&16+9) CALL ENUJOB RETURN	##ITE(&:10021) PERMAX,PERAVG 1992) FORMAT()H0,22HMAXIMUM PERCENT ERROR*E16.9,6%,22HAVERAGE PERCENT *ROH=E16.9) CALL ENDJOB RETURN END

WEORALS ROWLANDAT HSQ 0.07-01/10-0 SUUKOUTINE RUNT ENTRY POINT GOC 270 ENTRY POINT 000273 REDIEN walling. ENTRY POINT 000320 CLOSE --- ENTRY POINT GG0342 uPEN ENTRY POINT COUSSI ENTRY POINT OCCIAC 108088 STURAGE USED: COUE(1) 000402; DATA(C) 000127; BLANK COMMON(2) 000000 EXTERNAL PEFERENCES (BLOCK, NAME) 00U3 10mK E01.4 しんじゅう シンチ 61025 8397 0.110 N51025 DOLL NERRAS STURAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME) 0001 0000/1 Idl 0001 000116 20L 0001 000140 21L 0001 000242 2156 0000 058670 18GF 0001 000227 25L 0001 000234 26L --- 0001 000033 6L -GBD144 22L 0001 00021 24L 00ul 00ulu5 /_L -0040 | 000043 | FLD --- 0000 | 00011 | 1000 | 0000 | 000046 | 000046 | 000046 | 000011 | 000067-17#0 0000 1 000062 11 0000 1 000063 12 0000 1 000064 13 0000 | 000056 KNThD 0000 | 000040 KODE ONIDO 2. C GENERAL FORTHAN 1/O PACKAGE EXEC VILI APRIL.1970 READ/WRITE MAG TAPE OR DRUM IN FORTRAN OR NON-FORTRAN FORMAT. . - - ------------Colug SUBSTUTENE ROST Delnt: -- 5▼ DIMENSION ARRAY(11.1CHO(3).1FLD(29).KODE(6).1PACKT(8).KNTWD(3) 00103 DATA (IFLU(1),1-1,29)/1H1,1H2,1H3,1H4,(H5,1H6,1H7,1H6,1H9,2H10, 20104... - 7* . 12H11,2H12,2H13,2H14,2H15,2H16,2H17,2H18,2H19,2H20,2H21,2H22,2H23, C0104 R = 00104 27H24.2h25.2h26.2H27.2H28.2H29/ CLIDA 10-DATA (KOOE(1):141:6)/0304300000000,0002000000000015000000000 00106 11 * 12-DATA 11/262144/.12/1073741824/.13/0010001/ CC110 60114 . . 13 . . DATA IBLANK OH 00114 19.5 ENTRY REDIPRIJUNIT, MODE, LERR, NW. NWOS, ARRAY) 00116 - 150 # #1 KEAD FIN FORMAT #2 READ NON-FIN. 00120 16. 10P≖MODE 00120 17+ 20121 160 DC122 -- L94 -- ENTHY AHITER (JUNIT, MODE, LENR, NNDS, ANRAY)

```
@ #3 + ARITE FTN FORMAT . #4 + HRITE NON-FTN .
30124
        2ú•
                    TOP=MODE+2
            KNTWU(1) - N&DS - 11+13 ... F BUILD FORTRAN RECORD-CONTRDL NORD . ...
Ec125......21+.
                                         & DUMMY CHECKSUM ERROR WORD.
00126
        22+
                    KNTWD [2]= 18LANK
0n127--- 23*
                   KNTWD(3)=KNTWD(1) -- ...
66130
        294
                   GO TO 10
00130
        250
Ca131
         26 .
                    ENTRY CLOSE ! JUNIT, JOP )
66133
       --- 27 •
                  · [[h0=1
                                ....
00134
         26 €
                    ED TO (6.6.7.25). JOP & JOP#4. NO ACTION. RETURN.
                                         @ JOP=1.2, WRITE EOF AND REWIND JUNIT.
06135
        294
                  6 1TH0=2
00134
        31.0
                  7 TOP#5
                                         # ms, walte End-of-File.
00137
         31+
                   60 Tu 10
00137
         ٠2٠
                   ENTRY OPENITURIT. JOF)
00140 ****
        33.
                                         6 JOP 2.3. NO ACTION RETURN.
00142
                    IFIJOPAGTALI RETURN
         14.
         35 .
                  8 401 B
                                         & =6+ REWIND JUNIT.
£0144
90145
                   66 16 16
         * ب ز
                                                                           00145
        37 +
                    ENTRY IDROWR(ICODE, IUNIT, LADORS, ARRAY, NWD5, IERR)
00146
        38*
                    IF (ICODE, EQ+1) [DP=4 @ +4. SEQUENTIAL WAITE.
00150-
        39+
                    IFIICODE.EQ.2) IDP=2 & =2. SEQUENTIAL READ.
80152
         40+
                                        # BEGINNING DRUM-SECTOR ADDRESS.
00154
                  . IPACKT(6)=IACORS
58154
66155
                 is continue
         430
E0156
         44 *
                    IFACKT(1)=IFLO(IUNTT)
                                                  B IUNIT IN FIELD-DATA.
                                                        ---
00157
        45.
                    IPACKT(2)=1BLANK . .
00160
         46+
                    IPACKI(3)=0
                                                  @ OPERATION CODE TO TOWS.
        47 4
                 II 1PACKT(4)=KODE(TOP)
00161
CC162
         46.
                    60 TO 120,21,20,21,22,221,10P
                                                  @ FIRST CONTROL ACCESS NORD. --- ' ...
         49.
                 20 [CHD(1)= 1+11+LOC(KNT#D(1))
00163
      *DIAGNOSTIC* THE VARIABLE ARKAY IS DIMENSIONED.
66164
                    ICHD(2) =N+OS+11+LOC!ARRAY!
                                                  SECOND CONTROL ACCESS WORD.
CO164 -- .. 504
00165
                    1(a)(3)= 2 = 11 + LOC (KNTND[2])
                                                  & THIRD CONTRUL ACCESS #OKD.
         51.
                    [PACKT(5]= 3-11+LOC(1CHD(1))
                                                  @ NMBR AND LOC OF 15T C/A MORD.
00166
        52 •
G2167
      : 53*
                    GO TO 22
00170
      *DIAGNOSTIC* THE VARIABLE ARRAY IS DIMENSIONED.
                                                  & NABR AND LOC OF DATA BORDS.
00170
        54.
                 21 1PACKIIS1=NAUS+II+LOC(ARRAY)
                                                  & ROUTINE TO ISSUE EXEC REQUEST .....
5017 F
        .44.
                 - 22 CALL LOWN(1PACKT)
                    1F (IDP +EQ+6) RETURN
                                                  # RETURN AFTER REWINDING LUNIT.
00172
        56*
                    1F(10P-E4-5) GO TO (25.8), [TAO
                                                 6 ling=1.RETURN, =2.REWIND tUNIT+
56174 .
        57.
                                                  & ERROR STATUS IN SI PORTION.
         500
                    TER8 # 1 PACKT [41/12]
00174
                  - IF (LEKR-EU.C) GO TO Z4
                                                  & NORMAL OPERATIONING ERROR.
06177
                    IF (IERR+GE.3) GO TO 26
                                                  W TERMINATING ERHOR.
D0201
         + ن ہ
                                                  & END-OF-FILE OR END-OF-TAPE.
00203 ----
        61+
                  - IERR#2
00204
        62 .
                    RETURN
                                                  & NW FROM FTN CONTROL WORD+
                -- 24 NW=KNTWO111/11
- 00205
        63∓
                   IFINODE . Ew. 1) GO TO 25
60206
        64*
                                                                              00210 ----
        65 •
                    NAMIPACKT(4)-IPACKT(4)/II+II
                                                  # NA FROM TOAS.
00211
                 25 TERR#1
-- 60212 ---- 67 .... RETURN
        ი მ •
                 26 WRITE(6.1001 (1PACKT(1).1-1.6)
Ca213
                60221 -- 69*
       73 €
                   114H 1/0 PACKET 15 6016 1
0.1221
05222 ---- 71+
                    STOP
        72.
05223
```

TABLE 2. (Continued)

The second second is also as a second			Î	U 1	~ G !!		ıíca•			
: GASMAIS TOURATION	H									
ASM14F-01/19+01:	OS+Lig).			-						A
1 .								5(1)	AXR5	
	000000	27	aa	14	13	3	000000	IOAR*	L	A0,0,X11
3. ∪	0១១៦គ្ន	72	11	O Ç	00	0	000000		£R	1045
	033302	74	04	QΟ	13	Ð	000002		د ســ او	2+X11
[′] 5•									END	

TABLE 2. (Continued)

#FOR,1S INVRT,1NVRT #SO-004=01/19=01100-4.0)	
م العمل في دول العمل و العمل و المستقد و	
SUBROUTINE LAVAT ENTRY POINT COC370	
	
STORAGE USED: COOE(11.000416; DATA(3) 000334;	BLANK COMHON(S) 000000
EXTERNAL REFERENCES (BLOCK, NAME)	
Entering out months to be and the second of	
0003 HERR3\$	
STOMAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOC	CATION, NAME?
0001 000010 1116 0001 000144 115L	0801 000027 1176 0001 000034 12360001 000042 131
ეკე ევეც4 (62g ეივ1 გულგი 181L	0001 000166 2016 0001 000206 2076 0001 000230 220
	0001 000312 2456 · · · · 0001 000346 250L 0001 - · 000071 75L
paul 000073 7au -0001 000110 904	0000 0 000002 AMAX
0000 1 000274 1HD 0000 1 000100 1NDEX	CCCC I DOUDD I APLACED ODOG SAN DEEDOG I PI
0000 0032/5 H 0008 000273 J	DOGO 1 000272 K OGGO 1 000277 L 000D 1 000271 NN
ტულა დ შებყვე ბ S 1G#	*****
The second section is a second section of the second secon	
DOID1 1. SUBROUTINE INVETCA, N. M. DETER	R)
	· · · · · · · · · · · · · · · · · · ·
GOLDS 2. PARAMETER 101H=60	
GOLDS 3+ C MATRIA INVERSION AND SIMULTA	N OR AUGUMENTED MATRIX FOR SIME. ERS. 19520030
	s ·
CO103 B+ C DETERMINANT OF COEFFIC GO104 9+ DOUBLE PRECISION A(1),DETERM	
OUTOS DIMENSION INTO INDEXT	
GOIGS 11. DETENUI-GUO	
C0107 12* \$19N=1.000	and the second s
G0110 13 00 20 J=1+N	
03113 144 20 191V(J)#3	
Q0115 15= NN=N+M	
COILS	
\$0121 174 AMAX=0+000	
20122 - 18* 40 00 74 [*] IN	
GS125 19* IF [IPIV(1)*1)50.76.50	
00130 20+ 50 00 75 J#1+N	
00133 21* IF ([PIV(J)=1)55,75,250	
00136 22* 55 [ND#iJ#i]*N*I	and the second s
60137 23* IF(AMAX=DABS(A((NU))) 60+75	
00142 - 244 - 65 IR-1 60143 - 256 - 15EJ.	
60143 25. IC=J.	A MARK AND
The state of the s	

0151	29+	{P;V(1C) = }P{V(1C)+1	
0152 -	33.		
0155	+DIAGNO		
- 155 -		IF (H-1C190, 15,90	
0160	32*	93 SIGNE-SIGN	
0161	33+	00 110 L=1,NN	
0164	344	IND*(F+f)*N+IB	
0165 1	_	1NU2=(1=1)=N+1C	
0166	304	AMAX=A(INU)	
0167	37 •	A(1N0)=A(1N02)	
0170	344	113 A(INO2) = AMAX	
3172	37.	115 1VDEX(K.1)=1R	
0173	4.3+	140Ελ(Κ.2)#1ς	
0174	· ні*	10 10 10 11 11 11 11 11 11 11 11 11 11 1	
0175	42+	ARAX=A(IND)	
0176	454	DETER = DETER = AMAX	
0177	યુવુત	145 4(170)#[:uD0	
200	45	00 125 F=1'kW	_
1203	40	140=(L-1) •N*1C	
,203 3204 -		- 15g A(IND)=4(IND)/AHAX	
5206	4 + *	no 191 f=1.4	
206	49	. IF (L-1C)165,181,165	
1214	50.	165 180=(1C-1)*N+L	
1215	51*	AMAX#A(IND)	
216	524	COD.C=(ANI)A	
1217	51*	po 180 1*1.Nh	
1227	544	[NO={[-1}+N+L	
1223	55*	1N32=(I-1)+N+!C	
1223	561	A (I NO) = A (I NO) = A (I NO 2) * AMAX	
7225	57=	183 CONJINUE	
227	- ر د د	161 CONTINUÉ	
,231	. 54+ ··	182 CONTINUE	
233	60+	po 235 1=1.N	
236	6 L *	L = N + 1 = 1	
237	o 2 *	1R=1RULX(L,I)	
240	63	1C=100EX(L,2)	
241	64 ·	1F (1R-101210,235,210	
291 1294 -	07*	21g no 230 K=1.N	
		· · · · · · · · · · · · · · · · · · ·	
247 250	67 * *	[NO=(1R-1)=N+K	
.251	000	1NOZ=(IC-1)*N+K AMAX=A(IND)	
252	69+	A(1ND) = A(1ND2)	
253	73*	23g A(IND2)=AMAX	
255	-	239 CONTINUE	· · · · · · · · · · · · · · · · · · ·
257	72*	DETLK=\$1GH+DETER	
200	73+	RETURN	
261	/4+	25g M=-1	
262	15*	2=5 RETURN	-
263	76.	END	

```
GFOR IS DHATML . UMATHL
SUBRUUTINE OMATHL ENTRY POINT COCIÓC
EXTERNAL REFERENCES (BLOCK, NAME)
 DOUB NERHAS
STUMAGE ASSIGNMENT (BLOCK, TYPE, RELATIVE LOCATION, NAME)
                               aut a0a046 3c
               3031 000652 4L
0000 1 00001 LN 0000 1 000017 LN 0000 1 000014 LP 0000 1 000014 LP 0000 1 000012 LC
--- 0000 1 00001 Lm -- 0000 1 000017 Lm
            SUBROUTINE SMATML (C+A+8+M+N+K)
Cotol
00101
            GEHERAL MATRIX MULTIPLICATION ROUTINE WITH TRANSPOSE OPTIONS
             MHERE, M IS THE NUMBER OF ROWS OF (A)
00101
TRIBSPOSE OPTIONS ARE CONTROLLED BY THE SIGNS OF M AND No.
83101
    7 • · · C
            THE FOLLOWING PRODUCTS MAY BE OBTAINED
ដ0រមា ដូ ខ+ ៤......
            (C)=(A)(b) M AND N POSITIVE
50101 1 90 C
                      M NEGATIVE FOR LAST
00101 -- 100
             (c)=(a)7(a)
             (Cl=(A)(c)T
                      N NEGATIVE FOR (817
60101 11+ 6
         C - (C)=(A)T(9)T M AND N NEGATIVE
00101-----12***
00101 13 C
             WHERE T INDICATES TRANSPOSE
             IF M IS NEGATIVE. M IS THE NUMBER OF ROWS OF (AIT
00101--- 144
             IF N IS NEGATIVE. W IS THE NUMBER OF ROWS OF (BIT
00101 15+
00101 ... 164
Daigi 17*
            DUTPUT ARGUMENT * C
frain3 --- -- te . --
            DIMENSION CLI)
    19.
forting.
         C# INPUT ARGUMENTS * A B M N K
00103
    - 20●
    21 *
            DIMENSION A(1) 8(1)
20104
60104
     22.
00104
     214
CD105 - 244 - DOUBLE PRECISION CD.C.A.d
00106
    254
            143=1
00107 -- 26-
         . . . [M= IAdSIM]
         1##1465(N)
60110 27*
         IECH +LT+ DIGO TO ;
00111----28*
           ÎA1=LH
Da113 29*
Coll4 --- 13* --- ta2*1
```

TABLE 2. (Continued)

00115	31*		GO TO 2
 -00116	• ۾ و	1	. [A]. = . [+
90117	33+		1 A 2 = 1 N
00129	34+	2	IF(N'+LT+ 0)GO TO 3
Cp122	35 *		181=1
00123	30*		182=IN
00124	37*		GO TO 4
00125	38#	٠ ق	1319K
00126	39 *		192#1
-	4 ن 4	4	DO 7 LM=1:1M
20132	41.4		LC=LM
00133	42 *		183*1
8e134	430		00 6 LP=1.K
00137	44.		CO * 0.000 -
59140	45.		LA=1A3
00141	400		La=IB3
00142	47 .		DO 5 LN=1.1N
00145	430		CO = CO + A(LA)+B(LB)
69146	49*		LA=LA+1A4
C0147	50*	5	LB=LB+131
00151	51.		C(LC) = CO
00152	52*		LC = LC + IM
00153	53 •	6	163=183+182
00155			143=143+142
00157	55*		RETURN
00140	50 =		END

END OF CUMPILATION: NO DIAGNOSTICS.

TABLE 2. (Continued)

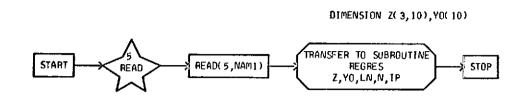
MHAP:15 AA:AA HAP—1782=01/19=01430	O F			
1. LIB 5755.				
	*			
		·-· ·- ·-		The state of the s
₽ ■ • • • • •	•			
AUDRESS.LINITS 001007 STARTING ADDRESS 033163		040300 05464	2	
AUROS DECIMAL 13448	. IHANK	6563 DBANK		
-				. , ,
SEGMENȚ MA	N	.001000 03320	7	040000 054642
NSATC#/FOH	1 00100	19 001021		, , , , , , , , , , , , , , , , , , ,
NRHLK\$/MSFCS5	1 0010	22 001110	ū	040300 040001
-			2	040002 040053
ALOGS/FURSI		14 931421	2	040054 040114
CS146V/SC4020		22 001710	Ö	040115 040153
2314017321020			2	BLANKSCOMMON
CERMRK/5C4020	1 9017	11 201740	ō	C40154 043167
Eg			2	BLANKSCUMMON
CLASUV/SC4020	t col74	11 003073	. 0	040170 040276
			2	BLANK5COMMON
MKWHUS/FORSU		14 903963	2	040277 040310
NaEFS/M5FC55		54 003320	2	040311, 040331
WEACHRIEGE2		21 003050	2	040332 040367
CYMQ04/5C4620	1 93963	11 003646	a	Q40370 G40376
			2	BLARKSCOMMON
CACCRY/SC4020	F 9039	17 003670	0	040377 040407 BLANK\$COMMON
CXM00V/SC4520		71 003716	á	048410 040414
CXR000/564020	1 0036	1 003/10	2	BLANKSCOMMON
CONCAT/ASFC	1 0037	7 054670	ā	040417 040440
SETINT/504020			ā	040441 040446
3511412 36 1050			2	BLANKSCOMMON
CHOLLY/SC4020	1 0041	24 004206	ō	040447 040463
7,000			2	BLANKSCOMMON
CHONUM/SC4320	1 0042	27 994614	D	040464 040535
			2	BLANKSCOMMON ,
CLIMRY/SC4020	t oc44	15 COS470 ···	a	040536 040451 1
	3 666		Z	ALVEK & COHMON
CYSCLY/SCHO20 · · · ···		71 005673	٥	043652 040790
	€ىئ د.		2	BLANKSCOMMON
CXSCLV/SC4020	1 4354	74 QC6076	C	040701 040727
	3 666		2	BLANKSCOMMON
CERNEY/SC4020	- 1- 0060	77 006253	0	640730 646742 ·····

					2	BL ANK & COMMON	
CERRLN/SC4D2O		.006254.	006363		a	040743 040760	
	-				2	BLANKSCOMMON	•
CSETC+/SC4020	- 1	004364	006424		Ĝ	040761 040771	
635161.301020	•	00.30,	000 1		2	BLANKSCOMMON '	1
CSETHV/SC4020	. 1 .	806425	004503		á	040772 641006	
C361HV/3C4020	•	200723	000203		,	BLANKSCOMMON	
CXAX15/5C4829	1		996797		6	041007 041042	
CARALS* 30 1020	•	00-554	420 5		2	SLANK SCOMMON	
VCHARV/5C4020	1 -	006710	007153		ć	041043 241062	
R1TE21/SC4620	í	007154			ă	C41043 C41111	
BPLOTK/5C4020	i	007435			ă	041112 041471	
BFC0147341029	•	60.405	447.443		2	BLANK COMMON	
CFRAM/504020		007465	007705	;	ć ·	041472 041556	
CHRAMISCIGES	i	GGG	207702	٠	2	BLANK SCOMMON	
CCAMRA/SC4ú2t	i	007736	007757		á	041557 04197C	
CCAPRAZZCIOZC	3	666	227737		2	BLANK & COMPON	
TABL19/5C4320	3	969			c c	041571 042111	
		up776a			-		
NaDCV#/FOR57	1				2	042112 042151	
NETYS/FOR			210136		_		
ACLOS#/HSFCS7	Ĺ	010137			Z	042152 042177	
NARLK#/MSFC57	i.	010304			٥	042200 042201	
NESSL # / FOR	1	010475					
NUPOAS/FOR	1	010533	313299				
NBFOGS/FOR					2	042202 044403	
NCNVT=/F0457	-	010567			2	044404 044473	· · · · · · · · · · · · · · · · · · ·
r[n[n3/n5fc55	1	011055			2	044474 044515	
CPLQTV/5C442D		011254	211434		C	044516 044554	
	3	GGG			2	BLANKSCJMM ^O H	
CLINEY/SC4020	1	011437	212722		0	Q44555 U44633	· · · · · · · · · · · · · · · · · · ·
					2	BLANKSCUMHON	
42CFA1\2C4050	- L ·	012023	212141		ป	044634 044644 -	
	3	G G G			2	BLANKSCOMMON	
X5CLV]/5C+020	1	012142	012257		ď	344645 344655	• • • • • •
	3	GGG			2	BLANKSCOMMON	
CAPLOT/5C4025	1	012260	012533		ď	044656 044731	
		GGG			2	BLANKSCOMMON	
CAPRNY/5C4322		012534	012616		ō	044732 044750	· · · · · · · · · · · · · · · · · · ·
•		•			2	BLANKSCOMMON	
CPRNTV/SC4020	1	012617	013210		ō	044751 045005	the state of the s
-1 11111 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	3	GGG			2	BLANKSCOMMON	
CGRD14/5C4020 .	1	013211	014115		ā	045006 045121	., .,
	3	666			2	BLATIKSCOMMON	
COXDYV/5CH020	-	J14116	014710		ū	045122 045206	
20,21,41,22,022	•	••••			ž	BLANKSCOMNOR	
CBH1TV/5C4020	1	014711	015312		ě	045207 045222	
CBHIIIIICIDEO	-	665	012211		2	BLANKSCUMMON	
CMARGN/9C4020		015013			ő	045223 045264	
CMARGN/3C4020	•	31-013	012411			BLANKSCOMMON ,	
CMBENK/5C4020		615073	A151		2		
CARENY SCACE		ŭ15072	712141	-	0	045265 045300'	The state of the s
Augustuses		0.5.40	A1E217		2	ULANKSCOMMON	
6HOV/MSFC	3	015142	015424		a	045301 045311	
1	′ .				Z	BLANKTCUMMUN	
TRACE	i	D15223	015346		0	045312 045317	
					2	045320 045402	
>+CFRH/H5FC					U	045403 845456	

TABLE 2. (Concluded)

80xlTA/CSC 015646 016500
C1DENT/SCH020 1 016501 017683 0 048650 046033
NOTINS/MSFCSS
NOTINS/MSFCS5
NOUTS/MSFCS7
NEMTS/MSFCS7
NIOERS/MSFC57
NFCHK#/MSFC57
NTABS/MSFC55
NTABS/MSFC55
NEINPS/HSFC57 1 023074 024640 2 046557 046770 SWHTS/FOR55 1 024641 024700 2 046771 047002 NEXPSS/FOR57 1 024761 024764 2 047003 047012 GGG (CUMMON BLOCK) 047013 047146 047013 047146 CQUIKL/SC4020 1 024765 025402 0 047147 047231 3 666 2 6LANK\$COMMON 1DENT/SC4020 1 029403 024645 0 047232 051027 H\$MONITOR/HSFCS5 1 026646 027755 2 051030 051614 NIERS/FOR52 1 027756 030040 2 051615 051744 NGBUFS/FOR51 1 030041 030100 051615 051744 CRUSY/HSFCS5 1 030101 030435 2 051745 052121 BLANKSCOMMON (CUMMON BLOCK) 030436 030433 0 052122 052174 DHATML 1 030436 030433 0 052122 052174 2 8LANKSCOMMON 2 0470100 0470100
SWRTS/FORSD 1 Q24641 024700 2 C46771 047002 NEXPSS/FORS7 1 024701 024764 2 C47003 047012 GGG (CUMMON BLOCK) 047013 047146 047013 047146 CQUIKL/SC4020 1 G24765 025402 0 047147 047231 3 GGG 2 BLANK\$COMMON 1DENT/SC4020 1 G25403 024645 0 047232 051927 H\$MONITOR/RSFCSS 1 026646 027755 2 051030 091614 NIERS/FORS2 1 027756 030040 2 051615 051744 NGBUFS/FORS1 1 030041 030100 051615 051744 ERUS/FORS/FORS4 1 030101 030435 2 051745 052121 BLANK\$COMMON (CUMMON BLOCK) 030436 030433 0 052122 052174 DHATML 1 030436 030433 0 052122 052174 10VRT 1 030434 031251 0 052175 052530 2 BLANK\$COMMON 0 0 0 0
NEXPSS/FORS7
GGG (CUMMON BLOCK) CQUIKL/SC4020
CQUIKL/SC4020 1 024765 025402 0 047147 047231 3 666 2 6LANK\$COMMON 1DENT/SC4020 1 025403 026645 0 047232 051027 H\$MONITOR/GSFC55 1 026646 027755 2 051030 091614 1 027756 030040 2 051619 051744 1 030041 030100 ERUS/DFC55 1 030041 030100 ERUS/DFC55 1 030101 030435 2 051745 052121 04488/FOR57 1 030101 030435 2 051745 052121 04488/FOR57 1 030436 030633 0 052122 052174 2 8LANK\$COMMON 100000 1 030436 030633 0 052122 052174 2 8LANK\$COMMON 1 030634 031251 0 052175 052530 0 052175 052530
3 GGG 2 BLANK\$COMMON IDENT/SC4G2G 1 G254G3 G26645 G 047232 G51927 H\$MONITOR/RSFCSS 1 G26646 G2775S 2 G51930 G51614 NIERS/FOR52 1 G27756 G3004G 2 G51830 G51614 NUBUFS/FOR51 1 G3CG41 G3C100 ERUS/RSFCSS NERHS/FOR5/ 1 U3C101 G3C435 2 G51745 G52121 BLANK\$COMMON (CUMMON BLOCK) DHATML 1 G3C436 G3C633 G G52122 G52174 2 BLANK\$COMMON INVRT 1 G3C634 G31251 G G52175 G52530 BLANK\$COMMON
TOENT/SC4020
H#MONITOR/ASFCSS 1 026646 027755 2 051030 081614 NIERS/FOR52 1 027756 030040 2 051615 051744 NUBUFS/FOR51 1 030041 030100 ERUS/ASFCSS NERHS/FOR57 1 030101 030435 2 051745 052121 BLANKSCOMMON (CUMMON BLOCK) DHATML 1 030436 030633 0 052122 052174 2 8LANKSCOMMON INVRT 1 030634 031251 0 052175 052530 BLANKSCOMMON
N ERS/FOR52
NUBUFS/FOR51 1 030C41 030100 ERUS/N5FC55 NERRS/FOR57 1 030101 030435 2 051745 052121 BLANKSCOMMON (CUMMON BLOCK) DHATML 1 03C436 03C433 0 052122 052174 2 BLANKSCOMMON
ERUS/NSFCSS NERHS/FORS/ 1 030101 030435 2 051745 052121 BLANKSCOMMON (CUMMON BLOCK) DHATML 1 03C436 03C633 0 052122 052174 2 8LANKSCOMMON
NERRS/FORS/ 1 030101 030435 2 051745 052121 BLANKSCOMMON (CUMMON BLOCK) DHATML 1 030436 030433 0 052122 052174 2 8LANKSCOMMON
BEANKSCOMMON (CUMMON BLOCK) DHATKL 1 63C436 03C633 0 052122 052174 2 8LANKSCOMMON
2: 8EANKSCOMMON
2: 8EANKSCOMMON
2 BLANKSCOMMON
- · ·
10xR 1 031252 031254
RUNT 1 03#255 031456 0 052531 052657
2 BLANKSCOMMON
REGRES 052660 054541
2 BLANKSCOMMUN
Main: 1 033167 033207 0 054542 054642
2 BLANKSCOMMON
SY5\$#RL185. LEVEL. MS7-5
END OF COLLECTION - TIME 3.518 SECONDS

EXIT AA



DIMENSIONED VARIABLES

SYMBOL	STORAGES	SYMBOL	STORAGES	SYMBOL.	STORAGES	SYMBOL	STORAGES	SYMBOL	STORAGES
Y	10	RESID	10	Z	3, 10	SMALLZ	TO IM	SHAT	9,9
ZBAR	3,3	Y 0	10	BZ	10	В	3, 3	SVHAT	9,1
SMAL Z1	IDIM	SMALZ2	TD IM	SH	9,9	XX	10	ADARY	22
PMA X	10	FLDX	12	FLDY	12				

Figure 2. Operation of the computer program (noncross product).

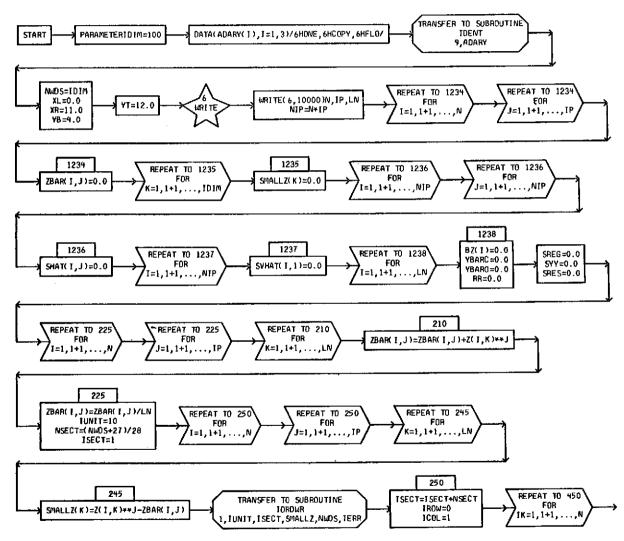


Figure 2. (Continued)

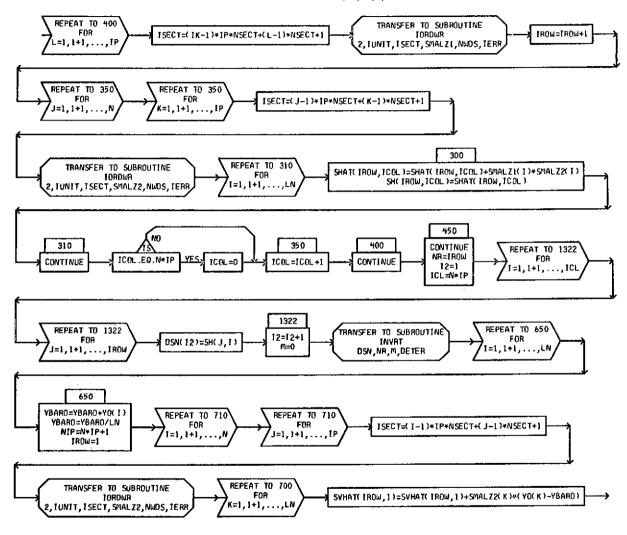


Figure 2. (Continued)

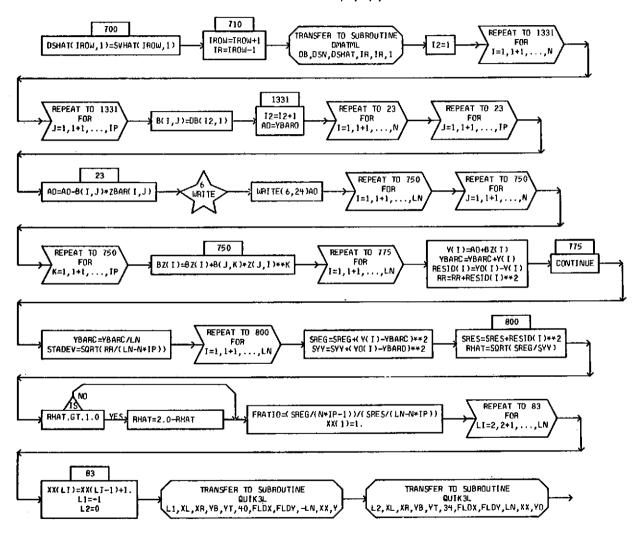


Figure 2. (Continued)

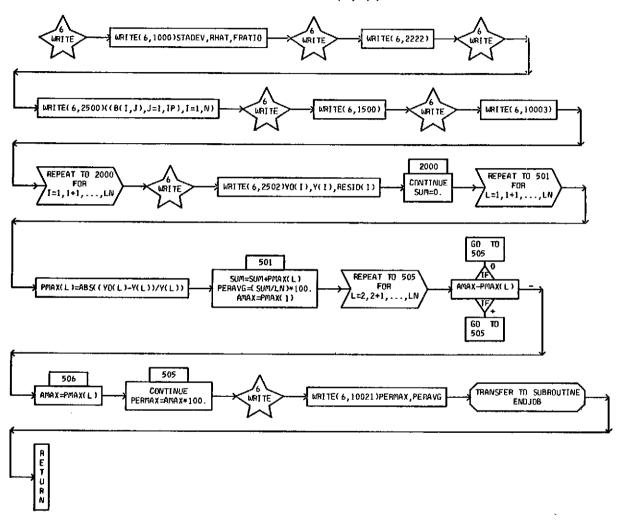


Figure 2. (Continued)

GENERAL FORTRAN I/O PACKAGE EXEC VIII APRIL,1970 READ/WRITE MAG TAPE OR DRUM IN FORTRAN OR NON-FORTRAN FORMAT.

DIMENSIONED VARIABLES

SYMBOL.	STORAGES	5YMB0L	STORAGES	SYMBOL	STORAGES	SYMB OL	STORAGES	SYM80L	STORAGES
ARRAY	1	1CMD	3	IFLD	29	KODE	6	IPACKT	8
NTWD	3								

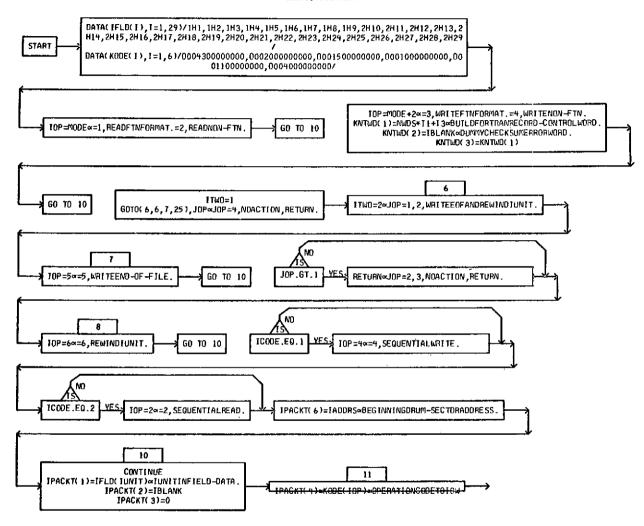


Figure 2. (Continued)

SUBROUTINE ROWT

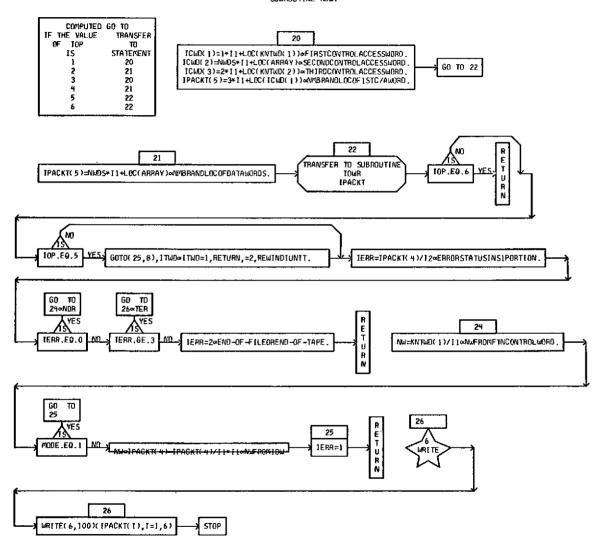


Figure 2. (Continued)

DIMENSIONED VARIABLES

SYMBOL	STORAGES								
ĪPĪV	IDIM	INDEX	IDIM,2						

Figure 2. (Continued)

SUBROUTINE INVERCA,N,M,DETER)

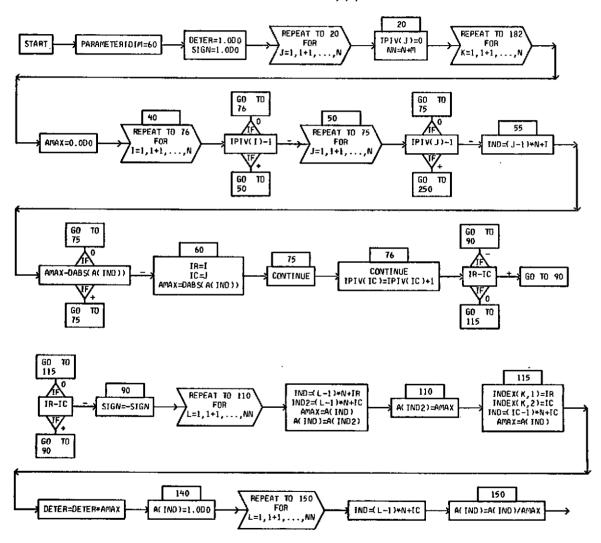


Figure 2. (Continued)

SUBROUTINE INVRT(A,N,M,DETER)

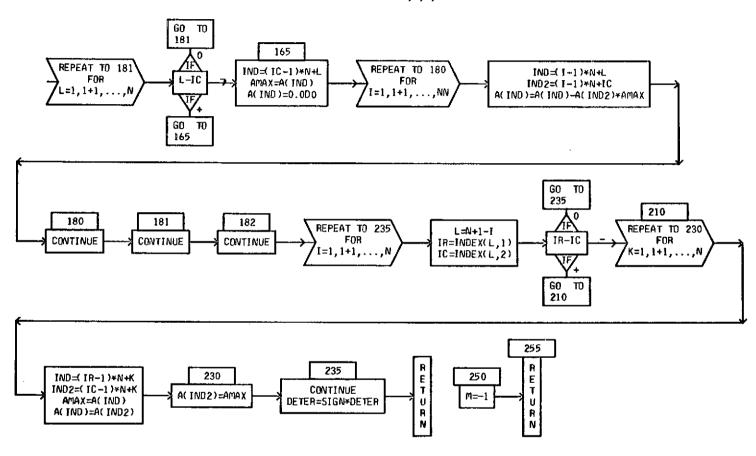


Figure 2. (Continued)

DIMENSIONED VARIABLES

SYMBOL	STORAGES								
C	1	A	1	R	1				

SUBROUTINE DMATML(C,A,B,M,N,K)

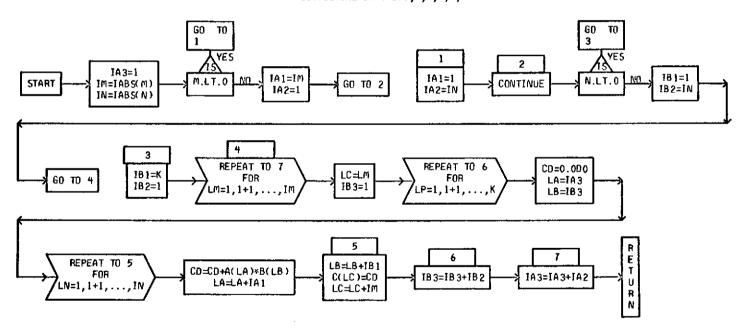


Figure 2. (Concluded)

Also included in the output are the number of independent variables N, the degree of the model equation P, and the number of input data points (sets) n denoted in the output as LN. Further, the significance of the estimated regression equation is indicated by the standard deviation, the multiple correlation coefficient, the F ratio, the maximum percent error, and the average percent error.

The values of the dependent variable are also shown for the input data and for the computed values obtained from the fitted expression for each set of data input, as well as for the residual difference in the input values and the computed values.

Plotted results are also obtained which compare the input and the computed dependent variables as ordinates to the point interval along the abscissa (which is normally one of the physical independent variables, but which can be a unit indication of each data set in order of input to the program). The computed points are connected by straight lines and are plotted with * symbols. The input points are plotted with + symbols and these points are not connected with lines.

D. Illustrative Problem

For the purpose of illustrating the use of the program and its capabilities the following arbitrary equation was selected for use:

$$Y = 9 - 6X_{1} + 7X_{1}^{2} + 5X_{1}^{3}$$

$$-4X_{2} + 1X_{2}^{2} + 7X_{2}^{3}$$

$$-6X_{3} + 7X_{3}^{2} - 6X_{3}^{3}$$
(37)

From equation (37) the following set of input data (Table 3) was developed containing exact dependent variable values (to three decimal places) for arbitrary values of the three independent variables.

TABLE 3. INPUT DATA, DEPENDENT VARIABLE VALUES

Data Point Number	Y	x ₁	x ₂	x ₃
1 2 3 4 5 6 7 8	5.719 7.111 5.216 5.592 10.915 7.569 7.450 9.618 5.019	0.5 0.6 0.2 0.2 0.9 0.7 0.3 0.9 0.5	0.4 0.3 0.6 0.6 0.0 0.0 0.9 0.3 0.6	0.4 0.2 0.6 0.5 0.5 0.6 0.7 0.6 0.7
10	8.021	0.3	0.8	0.2

The input for this sample problem was read in through namelist NAM1 as follows:

```
Col. 2

$NAM1

Z = 0.5, 0.4, ..., 0.2,

YO = 5.719, 7.111, ..., 8.021,

LN = 10,

N = 3,

IP = 3,

$
```

The computed results are shown in Table 4 for this example problem and the plotted results are shown in Figure 3.

The plot graphs the point intervals on the X axis against the exact and computed dependent variables. The exact dependent variables are plotted with (+) and the points are not connected with lines. The computed dependent variables are plotted with (*) and the points are connected by straight line segments.

Inspection of the digital and plotted results reveals that the computed regression relation yields an almost exact representation of the input data for this arbitrary case. Experience with many sets of physical data have also shown excellent results.

TABLE 4. OUTPUT DATA LISTING FOR ILLUSTRATIVE PROBLEM (CASE WITHOUT CROSS PRODUCTS)

AC= 1899989665+31				
STANGARD GEVIATIONS	.149373568-04 HULT	IPLE CORRELATION COEF	FICIENT +999999974+0	0 F RATIO# +190450271+11
8 COEFFICIENTS				
#+599952 072 + 0 1	•6998664Q8 + C1	•5000°0784+01	-•40nC01669+01	.999836586+00
•700004484+31	549887073+01	•6996 ⁸ 4674+01	-+599740386+61	
Yu .	, YC .	40-4C		· · · · · · · · · · · · · · · · · · ·
OBSERVEO	COMPUTED	RES!DUAL		
*571879798+31	•5 ⁷ 1900237*31	238418579-05		1 1
	•7 ¹ 1160280*C1	280191830-05		Marine A. N. de Alle, Seal (Marine) are Mills and Mills and Marine are serviced in the American Application of the American
+5216Uu002+31	•5216GC1G3*G1	101327896-05		,
•55926¢661+61	.559199862+01	.119209290-05		The state of the s
+109150600+02	+109150964*62	846385956-05		The state of the s
•/509@2081+31	•7>6897226*G1	.77486 <u>038</u> 2- <u>0</u> 5		
*144747979*01	•7 ⁴ 5000219*01	220537186+05		
461882863+31	•901749359+DI	. +643730164=05	and the second s	
+55189y499+ <u>4</u> 1	•501900327+01	327825596=65		and the second of the second o
+6221020 0 3+41	•B02099574±01	.429153442-65		
FIXITON PERCENT ENRORS	.102372490+63	AVERAGE PERCENT ERRO	R= •517097560=09	

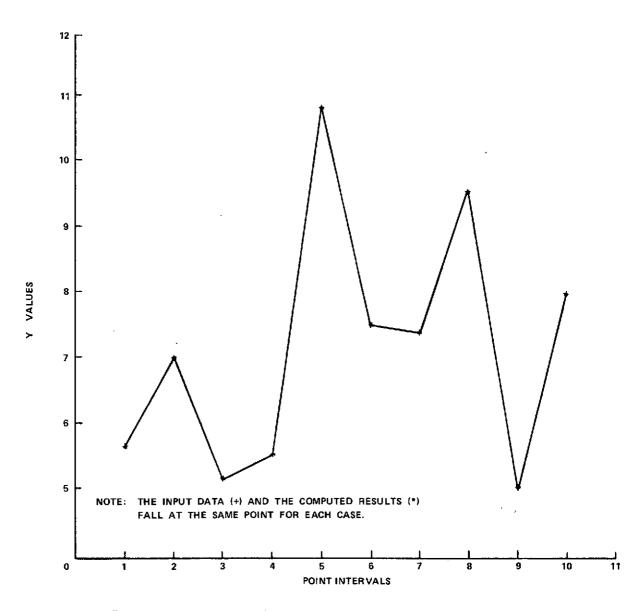


Figure 3. Comparison of input and computed values for illustrative problem without cross products.

APPENDIX B

MULTIPLE REGRESSION PROGRAM FOR CASE WITH CROSS PRODUCTS

A. Input Data

The regression subroutine is called with the following statement:

CALL REGRES(Z, YO, LN, N, IP)

where:

Z is a two-dimensional array containing the independent variables used. The first subscript denotes the independent variable and the second subscript denotes the data set.

YO is an array containing the dependent variables which correspond to the independent variables.

LN is the number of data sets.

N is the number of independent variables used.

IP is the degree of the polynomial curve fit.

These arguments must be assigned a value in a driver program.

The regression subroutine incorporates several special routines: RDWT, IOWR, INVRT, and DMATML.

RDWT is a general FORTRAN I/O package which is capable of reading and/or writing on magnetic tape or drum in FORTRAN or non-FORTRAN format.

IOWR is an assembly language I/O routine used by RDWT.

INVRT is a double precision matrix inversion and simultaneous equations solver. The call to this routine is:

CALL INVRT(A,N,M,DETER)

where:

A is the input matrix for inversion or augmented matrix for simultaneous equations.

N is the order of the coefficient matrix.

M=0 for inversion only; otherwise, M is the number of constant vectors.

DETER is the determinant of the coefficient matrix.

DMATML is a double precision matrix multiplication routine with transpose options. The call to this routine is:

CALL DMATML(C,A,B,M,N,K)

where:

C is the product of matrix A times matrix B.

A is the first input matrix,

B is the second input matrix,

M is the number of rows of A,

N is the number of rows of B, and

K is the number of columns of B.

Certain variables have dimension changes that vary depending on the number of data points (LN), the number of independent variables (N), and the degree of the polynomial curve fit (IP). These will be dimensioned as follows:

DSN(NCL2), DSVHAT(NCL,1), DB(NCL,1), X(LN), Z(N,LN), ZBAR(N,IP), ZZBAR(NN,IP), SHAT(NCL,NCL), YO(LN), SVHAT(NCL,1), YC(LN), BZ(LN), RESID(LN), B(N,IP), A(NN,IP)

where:

LN,N,IP are as defined above and NCL is computed as follows:

NCL = N*IP + N!/[2*(N-2)!]

NCL2 is NCL raised to the second power. NN is N minus 1.

SMALLZ, SMALZ1, and SMALZ2 should be dimensioned greater than the number of data points and the dimension is set in a PARAMETER statement; for example,

B. Program

In order to run this program on the UNIVAC 1108, the deck is set up as follows:

@RUN,//T JBNAME,320590,UDARBYBIN406,01.100 @ASG,T 10,F/1/POS/2 @FOR,IS MAIN, MAIN (Source deck for inputting data) @FOR,IS REGRES, REGRES (Source deck) @FOR,IS RDWT, RDWT (Source deck) @ASM,IS IOWR, IOWR (Source deck) @FOR,IS INVRT, INVRT (Source deck) @FOR,IS DMATML,DMATML (Source deck) @MAP,I AA, AA LIB SYS\$*MSFC\$. **@XOT AA** (Input data) @FIN

as illustrated in Figure 1.

A complete program listing for the case with linear cross products is shown in Table 5 and a flow chart indicating the operation of this computer program is indicated in Figure 4.

C. Output Data

The desired coefficients of the model equation are outputted in E notation where BHAT is the computed intercept A_O of the fitted polynomial expression and the B coefficients are printed out in ascending order of degree (P) with the first P coefficients indicating the b coefficients of the first independent variable, the second set of P coefficients indicating the b coefficients of the second independent variable, etc. The A coefficient designation represents the C coefficients of the various cross products in the following order:

$$c_{12}, c_{13}, \dots, c_{1N}$$

 $c_{23}, c_{24}, \dots, c_{2N}$
 $c_{N-1,N}$

Also included in the output are the number of independent variables N, the degree of the model equation P, and the number of input data points (sets) n denoted in the output as LN. Further, the significance of the estimated regression equation is indicated by the standard deviation, the multiple correlation coefficient, the F ratio, the maximum percent error, and the average percent error.

The values of the dependent variable are also shown for the input data and for the computed values obtained from the fitted expression for each set of data input, as well as for the residual difference in the input values and the computed values.

Plotted results are also obtained which compare the input and the computed dependent variables as ordinates to the point interval along the abscissa (which is normally one of the physical independent variables, but which can be a unit indication of each data set in order of input to the program). The computed points are connected by straight lines and are plotted with * symbols. The input points are plotted with + symbols and the points are not connected with lines.

D. Illustrative Problem

For the purposes of illustrating the use of the cross product program and its capabilities, the following arbitrary equation was selected for use:

$$Y = 9 - 6X_{1} + 7X_{1}^{2} + 5X_{1}^{3}$$

$$-4X_{2} + 1X_{2}^{2} + 7X_{2}^{3}$$

$$-6X_{3} + 7X_{3}^{2} - 6X_{3}^{3}$$

$$+5X_{1}X_{2} + 5X_{1}X_{3} - 6X_{2}X_{3}$$
(38)

TABLE 5. PROGRAM LISTING (WITH CROSS PRODUCTS)

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TABLE 5. (Continued)

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TABLE 5. (Continued)

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6011		9 •	0	IMENSION Z(3.15).ZBA	£(3,3),2	ZBAR (2,31,5MA	FFS(101W)			
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6013		23.	Y	T = 17,						
5014		24 •	ř.	1=1/, R(1E(6,10000) N,IP,L	N					
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COLO		34 +	16 2	(ZBAR([+J)=D+D						
0016	5.3	35.●	Ü	ic 7 I=1, LDIM						
0.000	5 h	36 €	7 5	MALLZ(I)=U+0						
6617	70	37 •	E	OO 8 1=1.NIP		•				
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002		46.		#LG=0.0						
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TABLE 5. (Continued)

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50222	51*		YY=0.0
00223	524		\$5±6.0
00223	53+	c	COMPUTE ZBAR
00224	54.	-	DO 125 I=1,0
00227	55.		DO 125 Jel. IP
50232			00 100 K=1,LN
00235	57.		2HAR(1.J)= Zbak(1.J)
00237	50 ♦		ZBAR(I.J)= ZBAR(I.J)/LN
00237	,59.●	C	COMPUTE ZZBAR
00242	÷0.5		K#1
06243	61.		60 150 1=1,NN
00246	62.		Kalifalia and a sure of the company
00247	٠٠٥		00 150 Jakan
00252	64*		UG 130 L=1.LN
CU255	65+		226AK([.J]@ZZ8AR([[J]+Z[],L]@Z(J,L)
00257	66.		226AR([.J]=226AR([.J])/EN
00257	67•	c	COMPUTE SMALLZ'S
06262	68.4		1UBITe10
00353	69.		1.5ECT=1N::05+271/28
00264	7 G *		ISCCT = 1
00205	/ L •		DO 200 I=1.N
CC270	72*		CO 200 J=1,IP
00273	73.		CO 175 K=1.LN
00276	74.●	175	SMALLZ(K)=2(1.K)=+4-YBAR(1.J)
00700	75.		CALL TURBER(1, [UNIT. 15ECT, SMALLZ, N&D5, LERR)
Disgr	76.	200	ISECT=ISECT+ASECT
00304	77*		KK=1
ប្រជាព	76 •		DD 230 1=1.NN
0.0310	79 *		K
60-11	9 ∁ ◆		UU 233 J≖KK.N
00314	81.		DO 225 KeliLN
00317	c 2 *	225	SKALLZ(K)=Z(I)K)*Z(J,K)*ZZBAR(I)J)
00321	b.i.e		CALL IORDWRILLIUNITAISECT, SMALLZANHOS, LERK)
00342	84 =	230	ISECT=[SECT+NSECT
00322	85 •	C	COMPUTE NUMBER OF COLUMNS
09325	86*		NFACT=1
00326	57 ◆		00 250 [ml.;
05331	68*	250	I.FACT=NFACT+I
50333	B * •		hf A C T 2 = 1
C0334	90.●		N2 = 11 + 2
00335	91 •		IF (NZ.EG.O) NZ#1
00337	92•		DO 275 1-1.N2
02342	4 J •	275	NFACT2=UFACT2+1
00344	74 •		NCOL=N+IP+(NFACT/12+NFACT2))
C(344	45.	Ç	COMPUTE ELEMENTS OF THE SHAT HATRIX
C0395	9 () ■		15EC1=1
00346	97•		MSECT=(NWDS + 271/28
00397	989 €		IRON=1
00350	94.		uo 310 J±1,NCOL
00153	1014		CALL TORDAR(2.)UNIT.; SECT. SMAL41, NWDS., JERR)
00354	1914		1C6L=1
00355	Lu2•		15ECT1=1 /
00356	1894		00 305 K=1.NCOL
(:)61	164 =		CALL TORORH(2, TUNIT, ISECTI, SMALZZ, NAOS, JERR)
06362	1 ∪5 *		00 309 Intaln
QC365	ដែក្	300	SHAT(IPOM. (CULI=SHAT(IRDA, 1CQL)+SHAL41(I)+SHAL22(1)

TABLE 5. (Continued)

00347	167+		1C0F=[C0F+]
00370	10a+		ISECT1=ISECTL+NSECT
003/2	104 🕨		18G2=180**I
003 73	116.	-31C	ISECT=ISECT+NSECT
00373	111+	-	COMPUTE SYNAT
S0375	112.		00 325 [=1,LN
ព្យុងថា	113 •		YBAP=YBAR+YQ(I)
00402	114 =		YBAK=YBARZEN
00400	115+		15€CT≃1
00409	116+		DO 353 K=1.VCOL
ርርዛሪን	117+		CALL TORONK(2,10h;T,15ECT,5MALZI,NADS,1ERR)
CCHIG	118*		DO 330 1=1.LN
00413	114*		SVHÁTTK,))=SVHAT(K,1)+SMALZ1(F)♥(YG(J)=Y8AR)
00414	120+		GSVH4T(K+1)#5VHAT(K+1) / /
20.10	121+		156CT=156CT+N56CT
00420	122 •		12=1
0.21	123 •		00 375 [=1:0COL
(-1, -24	124 •		UG 375 J=1.NCQL
96427	125 •		DSH(IZ)=5HAT(I.J)
05430	165		12#12+1
05933	127 4		NS=NCOL
66474	128 •		[2]=[2-1
20-34	129 •	c .	FIND SHAT MATRIX INVERSE
00433	1300		N=G
00436	131+		CALL INVRT (DSN, NR, M, DETER)
CC 436	132 •		COMPUTE & AND A COEFFICIENTS FOR THE ASSUMED MODEL
00437	133+		CALL DMAIML(DB,DSD,DSVHAT,NR,NR,1)
0.0450	134 -		12=1
00441	135*		00 400 I=1.N
00444	136 •		00 400 J=1.IP
00447	137*		4(T, J)=08(12,1)
00470	1377	920	[2512+1
00453	137*		12!=12
00454	140 • '		N#
ロシュラス	191+		DO HID INIM
00460	142*		K#K+1
DC491	1 4 3 •		DO YIO Jak,N
грнеч	144.		A([.J]#0#(IZ].[)
05465	145.	410	[2]=[2]+1
00470	146 •		üHAT=YBA6
00471	147 •		00 420 l=1.N
00474	190 •		DO 420 J=1,1P
00477	149•	42.5	TANBETAND TANBETAND
00502	130*		Kej
00/su3	151.		DO 425 I=1.NN
50506	152*		K = K + 1
00507	153+		DO 425 J=K,N
00212	154 •	425	BHAT=BHAT=A(I;J)*ZZBAR(I;J)
00516	55.		RRITE(6,10006) BHAT
09528	156 •	19006	FORMATITAD, SHBHATHE16.9)
00521	157 •		00 450 lalin
00524	150+		00 450 J=1.N
00527	159+	45.5	00 450 * cliff 4111-421114-41 11-11
00532	160*	776	BZ(11=HZ(11)+o(J ₄ K)+Z{J ₄ I)+eK
28536	161		DO 475 I±1, LN
00541	162 -		KK=1

TABLE 5. (Continued)

00342	163•	υυ 475 J=[,N]i	-
00545	164=	Κ ζ π 6Κ+1	
00546		· · · · · ·	
00551	las• 165•	00 475 L=KK, 6 475 BZ([)=62(1)+A(J,L)*Z(J,I)*Z(L,I)	
00551	157.	C COMPUTE THE T POINTS	
90555 90569	156*	00 500 T=1,CN	
0560	159× 178*	YC(I)=BHAT+BZ(I) *ESID(!}=YU(1)=YC(I)	
00562	1717	RR=RR+RE510(1)••2	
00563	1724	500 CONTINUE	
ر دهد 00	1/3•	Sux=0.	
00566	1744	06 531 E=1,EN	
003/1	175	PMAX(L)=ABS((YG(L)-YC(L))/YC(L))	
005/2	175 •	501 SUM#SUM+PMAX(L)	
00574	177.	PERAVSHISUM/LN) * LOO .	
00575	178 •	ANAX=PMAX(1)	
00576	179.	30 505 L=2.LN	
00-61	180 *	[F14MAX=PMAX{t;} 506,505,505	
00434	181.	506 AMARPHAK(L)	
ยกระธ	1020	505 CONTINUE	
00407	103 *	FLRMAXAAMAX+100.	
00610	1090	00 507 L=1.LN	
00013	185 ●	R=x+ABS(RESID(∟{)	
00614	186 €	Y = Y Y + Y O (L)	
53615	137 •	SOT CONTINUE	
00413	138*	C COMPUTE STANUARD DEVIATION	
90617	169.	N 2 = C	
00420	190 •	00 510 l=1,880 · · · · · · · · · · · · · · · · · ·	
00623	1914	$t \in I = \mathbb{N} + I$	
00024	192 •	510 42±32*NI	
99626.	173.	KMAT#M+IP+N2	
2007	1 /4 =	1947EN-KMATHID:EE:pD GO TO 513:	
00631	1954	STADEY=SURT(RH/(LN=KHAT-1))	
00632	176*	513 CONTINUE	
C) 532	197*	C COMPUTE THE MULTIPLE CORRELATION COEFFICIENT, AND FRATIO	
00833	194+	00 525 1=1.LV	
00436 00437	199• 236•	SHEG=SREG+ { YC (1) - YBAR) * * Z	
00637 00640	2000	SYY=5YY+(YO(1)=YBAR!++2	
00840	202+	\$5=\$\$+(YC(I)-YJAR]+(YO(I)-YC(I))	
00843	203+	525 SKE5*SKE5*KESID([]**2	- · · ·
03644 C3644	2034	EXTIO=(24EC/1XHAT+1))/(28E2/(FN-KHAT))	
00645	4 j 5 #	ORITE(6,10009) STADILY, HHAT, FRATIO	
00652	266.	10009 FORMAT(1H0,19HSTANDAHD'02VIATION=E16,9,4X,33HMULTIPLE CORRELAT	10N
Coak	237 •	*COEFFICIENT=E16.9.4X.8HF RATIO=E16.9)	1011
52553	243	AR(TE16,1001u)	
00655	237.	10010 FORMATTING LINE COEFFICIENTS)	
00656	210	AKITE16:10011) ((B[[:J]:J=1:[P]:[@]:N)	
00647	211.	10011 FURMATILE 15821,97)	
10570	2124	Ψα[[Ε(6+10012)	
C36/2	213.	10012 FORMAT(1HO,14HA COEFFICIENTS)	
006/3	21++	K=1	
00674	215	00 535 1=1, NN	
59577	216	K=K+1	
00/00	217	00 530 J=K,N	
00/03	213+	4817E(6,10019) A(1,J)	
		The second secon	*

TABLE 5. (Continued)

	ENO OF	COMPIL	ATION:	NO M DIA	GNOSTICS					
0 € 7 5 2	240+		END							
00121	239 =		STOP							
00759	238•		CALL ENDIOB							
CC / 47	237 ×	1234	"CONTINUE							
00745	236*	•	*ROR≄ E!6• Y}							and the common party of model and address of the contract of t
00746	235*	10033	FORMAT (LHO . 2	2 BEAXING	M PERCEN	T ERROR	= 216.9.6	X.ZSHAVERA	GE P	ERCENT ER
00742	234+		ARITE(6,1003							
50/41	233.		CALL GUIKBLE	L2,XL,XR	.YE . YT . 3	4.FLDX.	FLDY, LN,	(UY, X		
00740	232*		CALL QUIK3L	L1,XL,XR	, YB, YT, 4	O.FLDX.	FLDY LN	X YCT		
00736	231*	649	X(LI) = X(LI - I)	1+1+						
00733	230+		DO 549 L1=2	LM						
00732	229 •		X(!)=1.							
00731	228 •		1.2=0							1 1 M
00730	227 •	3	£1==1							
00727	226+		FORMAT(1H +3	£21.9/1						
00725	225+	1233	CONTINUE		.,	• • • • • • • • • • • • • • • • • • • •				
09720	224+		%RITE(6,1002		.YC(IS)	.RESIDA	LS)		-	
03/15	223 •	10025	00 1233 IS=1							
00714	222.	10024			-205N.12	r.ancom	PHIEG. 12	X.AHRESIDU	A I I	
00712	2214	,,,,,	ARITE(6:1002	4.1						
00707	223*	535	CONTINUE							
00706	219*	10014	FORMAT (1H .E	21.91						

TABLE 5. (Continued)

arok.is k	(641.6	1DAT												2. 4
HS0 009-0			.0.											
SVBRCU	UTINE	ROWT	ENTRY POLI	T 000270	3									
		REDIPH	ENTRY POLI		-									
		ARITER	ENTRY POI											
4		CLOSE	ENTRY POI		-									
		OPEN	ENTRY POI											
		TORDAR	ENTRY POI	¥T 000365)								-	
. l. 10.		i e conf	(1) Dec4644 (ALACYS	toria i	LANK ZON	MCM (21	noenne						
21001.	41 USI	2,. 0004	(1) 500 (021)	, K A () .	,001271 0	ERAK CON		00000					-	
EXTERN	NAL me	EFARENCE	S (BLOCK, NA	×Ε }										
0063	107	18												
0004	3,8.5	₹н2\$. •									
3365	N 1													
3006	610													
8907	410)23												
3015	· 5 T	T025												
6311	. NEB	₹₹3.5												
STURAC	SE AS≿	TABMMO1	(BLOCK, TYI	E. RELAI	IVE LOCA	TIÙY, NA	(1E.)							
0061	0.60	0071 105	0000	003470	1006	ocei	050116	20L	0001	000140	216	1005	000242	2156
6261		1144 226	0061	050211		0001	030227	251	0001	060234	261	0001	500033	6 i
9961		::	0001	800250			300061	,		0000065			. 000000	_
				000111			033946			003046			- 00a067	
		1662 [1		000043			000764			ეცსე56			1 000040	-
			-			-				*** -* **	.			
90103	1,	(• •					*							
00:00	2 •	c	GENERAL FORT	4AN 170 8	ACKAGÉ	£λ	1117 23		AMRIL. LS	7.0			•	
00100	3 +		READZORITE M.											
00130	4 .	C + +												
20101	5 .		SUBROUTINE RI									1 12 1	,	
0.0303	5 ×		OIMENSION AKI	iayı .[) • I	(C+D(3)+1	ELU(23),	K4061A1	.IPACKT(8) .sNTwo(3)				
6.109	7 *		DATA LIFED(I											
0.0004	성호		2011+2512+24				19.5418	• 2H 2Q • 2H2	1.2822.2	H23:				
00104	9.		ZH24 . ZHZ5 . ZH				- •			_		*		
COLUM	i u +	1	DATA (KUDE(I	1 + I = I + 6 1 /										
00106	13.	_						100010004	00000000	U/				
00110 70114	12* 13*		DATA 11/2621		2/3/31329	1,1137081	30017							
75117 00114	14+		DATA TREAKE	211						•				
00119	15.	-	ENTRY REDTRA	110657	116.1599	No. 33 SAS	4.7.2.4.4.4.4.4.4.4.4.4.4.4.4.4.4.4.4.4.							
00120	l ń #		IOP=Mag€					= 2 . READ	GON-FIN-					
00120	17.	(*****			1 1									
		•												-
20121	19.		60 TO 10											

TABLE 5. (Continued)

Collab	2.1.	: OP=MODE+2	& m3.4RITE FIN FURMAT. #1.WRITE NON-FIN.
00124	20.		
50123	21 •	K11+1[=20*N=(1)U*TH)	R BUILD FORTHAN RECORD-CUNTROL YORD.
00152	22	K YTHU (2)=LHLANK	G DUMMY CHECKSUM ERROR WORD.
00127	234	K N T A D (3) = KN T A D (1)	
00130	2 + •	G0 T0 10	
36130	25+	Charas	
00131	26 • 27 •	ENTHY CLOSE ([UNIT.JOF	· ·
00133 00139	28 *	(17,0°) Go TO (6,6,7,25),JJP	S JOPER, NO ACTION RETURN.
90135	20.	4 11x2=2	@ JoP=1.2. write gor AND REGIND TUNIT.
00136	30*	7 10P=5	G =5, SRITE END-OF-FILE.
00:37	31.	60 FD 10	MANAGER CHAPTER CONTRACTOR CONTRA
0013/	32-	(*****	
00140	• ڏڏ	ENTRY CREMITONITAGE	
00192	3 4 -	IF (JOP. GT. 1) RETURN	© JOP=2.3. NO ACTION.RETURN.
00144	3 '3 ●	4=401 9	# =6. REWING IUNIT.
00145	360	GU TO LO	
00145	37 *	C*****	
90146	38 •	ENTRY (ORDWRELEDDE, 1)	INIT, LADORS, ARRAY, HADS, IERR)
00150	370	IF (CODE . EQ .) 10P=4	4 =4. SEAUENTIAL WRITE.
00152	40.	(#110006.E4.2) [OP=2	₩ =2. SENDENTIAL READ.
00154	91=	IPACKT(o)=laudk5	& BESINAING DRUM-SECTOR ADDRESS.
03124	3.2 ●	C#4***	
80155	43+	IS CONTINUE	
00155	4 4 •	ITACKT (11=1FLD ([UN] T	G TUNIT IN FIELD-BATA.
00127	45=	-IPACKTLZ1#13LANK	
20162	46.●	12¥CK1131⇒A	
20151	47≠	II IPACKI("I=KODE(IOPI	S OPENATION CODE TO 1045
00162	430	50 To (20.21.20.21.2)	
00169 00169	47* *3145805	20 (C4D(1)= 1=11+L0C() STIC+ THE VARIABLE ARRAY 1:	
04164	5)4	1040(2)=7405411+L361	
00165	510	1(,)(3) = 2.11+1.0(1)	
Culos	52.	[PACKT(5)= 3+1]+LOC(· · · · · · · · · · · · · · · · · · ·
00167	530	60 FJ 22	m miles and been at 150 cm and the
33170		STICO THE VARIABLE ARRAY I	s ntwew510¥6n.
00170	44.	2) [PACKT(5)=4465+[1+L0	
00171	55	22 CALL 10 HK (IPACKT)	S ROUTINE TO ISSUE EXEC REQUEST.
00172	56.	IF(10F.Sq.o) RETURA	& RETURN AFTER REWINDING LUNIT.
50174	57.	IF (IOP.EQ.5) GO TO I	
00176	54.0	IERR=[PACKT(4)/[2	& EHROR STATUS IN ST PURTION.
90177	59 .	IF(IETR . EQ . Q) GO TO	
00201	• نا ن	IFILERH. GE. 31 GO TO	
00203	61*	1ERR=2	# END-OF-FILE DR END-OF-TAPE.
09234	62 a	RETURN	
00215	63*	24 Ha=KHTHD(1)/11	# N# FROM FIN CONTROL 9080.
00005	5 → •	01 00 (1.49.300%)31	25
00210	D 3 *		4}/11911 G_Nw_FROM IO+S+
00211	66.	Z5 [ERd=]	
00212	610	RETURN	and the second of the second o
00213	634	ZA NR; TELA-100) TIPACKT	
00221	270		RECUTION TERMINATED IN "ROWE" I/O ROUTINE. //
0.0551	70.	FINH IVO PACKET 15 60	16 1
0.3575	71*	STOP	
00583	72*	EVO	

TABLE 5. (Continued)

GFOK, IS 10 HSO 009-01														
SD980A.	TINE !!	NYRT	ENTRY POIN	.T 000364				· · · · · · · ·						
STORAGE	E USED	: cop	£(1) 000412; 0			ANK COM	MON(2).	00000						
EXTERN,	AL REF	£RENC	ES (BLOCK, NAM	E)										
2003	WEKK	# į												
STORAGE	E 2551	GNMER	T (BLOCK, TYP	E, RELATIVE	LOCAT	194 " NE	ME) .							
	0001 0002	10 15 62 23 73 76 42 16	75 .0001 116 0001 .L 0000 0	000140 150 000162 1760 000332 2350 0 000002 AMAX 0 000146 NO2 0 000140 K	· ·	0001 0001 0000	000254 000305 000141	1816 2426	0001 - 0001 0000	000202 000342 1 000144 1 000004	2046 250L 10	1000 1 0000 1 0000	000042 900224 000071 000142 000143	215g 75t - Ind Ir
00101 00103 00103 00103		Ç	SUBROUTINE IN PARAMETER 101 MATRIX INVERS A= WOUT MATRI	[M±3D 	LIANE	oUS giju R AdoUt	ATIONS .	SOLVER	R SIME.	EQS. 16		.,		
00103 00103 00103 00103 00104 00105	5* 6* 7* 0* 9*	c c c	#=0805R OF CC #=0 FOR INVER #=NUMBER OF L DETER=DETERMI DOUBLE PRECIS DIMERSION IP	JEFFICIENT HA RISON ONLY JONSTANT VECT INANT OF COER BION A(11,0ET	THIX TOUS TRICIE TEKISI	NI MATH GN,AMAA				16	500040			
00107 00110 00113 00115 00115	11+ 14+ 13+ 14+ 15+ 15+	25	05754=1.000 516%=1.000 00 20 J=1,N 01 P[VIJ]=0 NN=N+M 00 182 K=1.N AMAX=0.000											
00122 00129 00130 00133	17* 16* 17* 20* 21* 22*	St	0 00 76 1=1,N IF ([P]V([]+) 0 00 75 J=1,N IF ([P]V(J)+) 6 [No=(J-1)+N+)	1150.76.59 1155,79,250 <u>.</u>										
00142 00143 00144 90145	23 • 24 • 25 • 20 •	75	1F(AMAX-DABS) 1R=i 1C=J AMAX=DAUS(AC) 5 CONTINUE		,75,75				- · · · · · · · · · · · · · · · · · · ·					
	2## 294	7 -	30611403 ≀ 191≠(211749)	v(IC)+1										

00152	30 •		1F {19-1C}90,115,90
00155	310	90	SIGN=SIGN
20156	32+	. •	DO 110 L=1.NN
00141	3.3 *		IND=(L-1) *N+1R
00162	340		1ND2=(L-1)+N+1C
50,60	350		AMAX#A(INO)
00164	36=		A(IND)=A(IND2)
50165	37+	110	A(1002)=AMAX
00167	380		INDEX(K+1)=[H
00170	39•	,,-	INSEX[K+2]=IC
50171	48 a		146=41C=1)*6+1C
00172	41.		AMAZZA(193)
00173	42 *		DETÉR=CETER*AMAX
00174	43.	146	A([NO)=1.000
00175	44.		00 150 L=1.55
00200	45 •		INP=(L=1)+N+1C
00201	46 •	150	ACIGGIBACINULYAMAX
00243	47.		DO 181 L=1.N
50266	લ છે જ		IF (L-(C)165,181,155
\$5,211	49+	155	IND=IIC-II* ++L
0.0312	56♥		AMAK#A(IND)
01213	51 •		040.0±0.000
00214	520		CO INC I=1.NN
85717	530		INL=(1-1) +N+L
01,720	54*		Inps=([-1)*9+1C
1:221	\$ '> a		A ((NO) = A (INO) = A (IND2) + AMAX
00222	56.	150	CONTINUE
CC244	5/4	191	CONTINUE
C : 226	56₹	182	
OF 250	5 1 ª		00 235 1=1.N
0.0033	61:0		L=1 + 1-1
Cicar	01.		IR=INUEXIL.11
00235	62 n		IC=[NDEX(L,2)
00236	€3.4		IF U19-101210.235.210
00241	64*	210	00 230 K=1.N
00244	6 -> •		INC=(IR-1)*N+K
00245	000		I 10 () 2 = (I C + I) + N + K
0.0246	67*		CGHI) A=XAMA
CC251	064		A { 1 N O } # A { 1 N O 2 }
06226	699	230	ATINO21=AMAX
00252	/⊍+	235	COSTINUE
00254	71≠		DETER=SIGN+DETER
C1255	12-		RETURN
0.0005.6)3+	2 5 C	N = + 1
0.1257	/4+	253	
66390	750		END
	THE ST.	CHRII	Attone bo midesoffics.

END OF COMPILATION: NO DIAGNOSTICS.

TABLE 5. (Continued)

6F0R,15 HSO 009-			.0)	
SUSRC	UTINE	DRATML	ENTRY POINT COCIEC	
\$10R¢	GE US		(1) 000176; DATA(0) 000053; BLANK COMMON(2) 000000	
EXTER	NAL RI	EFERENCE	S AN DEK NAKES	
6003	{ ₀ L !	RR3\$		
1				
STORA	GE AS	SIGNMENT	(BLOCK, TYPE, RELATIVE LOCATION, NAME).	and the second s
0001	D.C.	րը31 11	0001 000061 1306 0001 000067 1356	00ml 000102 1436 0001 000035 2L
0001		5046 3 ₁		
		yora ar gaga rak	pond a ponder cal decor a service that	0000 t 000013 ta3
		0004 IN	0000 000027 INJPS 0000 1 000015 LA	0000 1 000014 LB 0000 1 000012 LC
		0011 LM	0000 1 070017 EN 0000 1 000014 EP	and the second s
Corol	1.		SUBROUTINE DEATHL(C.A.B.M.N.K) AUSTRACT	
00161 00161	2 • 3 •	C ·	RENERAL MATRIX MULTIPLICATION ROUTINE WITH TRANSPO	SF DETIONS
00101	4.	C	WHERE, M IS THE NUMBER OF RUAS OF LAS	The second secon
00101	. •	č	N IS THE NURBER OF HOWS OF (B)	
00101	6.4	2	K 15 THE NUMBER OF COLUMNS OF (8) OR 'B)T	And the second s
00101	7 *	Ç	TRANSPOSE OPTIONS ARE CONTROLLED BY THE SIGNS OF MITHE FOLLOWING PRODUCTS MAY BE OBTAINED	AND N+
10100	H •	(
00101 00101	9 . 1 0 •	ć	(C)=(A)(B) M AND N POSITIVE (C)=(A)T(B) M AEGATIVE FOR (A)T.	
10105	11+	Č	(C)=(A1(B)) N NEGATIVE FOR (B)T	
00:01	124	Č.	(CI=(A)T(B)T M AND M MEGATIVE	Control of the Contro
00101	13•	Ç	WHERE T INDICATES THANSPOSE	
COLUL	14+	Ç	IF M IS NEGATIVE. N IS THE NUMBER OF ROWS OF (A)T IF N IS NEGATIVE. N IS THE MUMBER OF ROWS OF (B)T	a commence and the second seco
00101 00144	15. 16.	c	IE W 12 MEGALIANT & 12 THE JOHNSEN OF MORE OF 1811	
United United	1/*	C +	DUTPUT ARGUMENT . C	*
00163	18.	-	Olmension CII)	
COLUB	9.	Ç		
06163	20 €	ς.•	INPUT ARGUMENTS " A.B.H.N.K	
06:164	21 •		D[MENSION A(1),8())	
60104	22.	Ç	and the second s	
00105 00105	23 * 24 •	(-++	OUDALE PRECISION CR.C.A.B	**************************************
00100	25-		14331	The second secon
00107	25+		10=1A85(m)	and the second of the second o
00110	274		1 N = 1 ABS (N)	
COLLI	23*		IF48 .LT. D}GO TO, 1	
56113	27+		IA = 1 4	
0.0114	300		142#1 .	

TABLE 5. (Continued)

00115	31+		GO TO 2
00116	.i 2 *	1	1A1 = 1
00117	33•		I A 2 = I N
00120	م 4 ئى	2	IF (N .LT. D) GO TO 3
00122	350	_	181=1
00123	36 ♦		IBZ=IN
06124	37+		
00125	33*	3	181=K
C0126	39+	_	182=1
CC127	40 ●	4	DO 7 LM=1.1M
00132	41•		Ł C = L M
00133	42 •		18/=1
06134	43.		00 6 LF#1.K
00107	44=		CD ≠ 0.000
00140	45 •		LA=IA3
00141	46 *		Le=183
05142	4/*		00 5 LN=1,IN
00145	48 •		. CU = CD + A(LA)+B(LE)
001-46	49 *		LA=LA+; A1
00197	50.●	5	L3=L6+181
€Q to 1	51•		CILCI = CD
00152	52+		LC = 10 + 1M
00153	53+	6	183=183+162
66135	54.	7	1A3=1A3+1A2
00157	55•		KETURN
00160	56≢		₹ M D
			,

ENU OF COMPILATION: NO DIAGNOSTICS.

TABLE 5. (Continued)

6MAP.1 AA.AA MAP 17M2-01/16-	13;51:-(,0)	
l. L	[8 \$Y\$\$+M\$FC\$.	

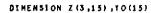
	•	· · · · · · · · · · · · · · · · · · ·
•		1
AUDKESS LIMITS STARTING ADDRESS	001000 033560 5 033540	040000 055012
WORLS DECIMAL	13681 18ANK	
wantes official	14.001 10%40	6667 GBANK
•		· · · · · · · · · · · · · · · · · · ·
SE	GMENT MAIN	001000 033560 040000.055012
LESTA CEON		
NSATCS/FOR		660 NGC1021
NABLKS/MSFC55		055 621110 0 040000 040001
1:12 55/15 5 657 1:05 5 7 5 6 6 7		111 001303 2 040602 040653
C51G6V/SC462C		304 001421 2 040054 040114
C21G0172C462C	1 0014	422 901710 . 0 040115 940153 2 8140K4C0MMON
CERFFR/SC4020	1 0017	711 001740
		2 BLANKSCOMMON
CLASE #/504020	1 0017	741 CC3503 - 0 - 040174 040276
		2 BLANKSCOMMON
NEZADS/FORSO	1 0030	094 003063 2 040277 040310 .
KV EFS/KSFC55	1 0030	064 003320 2 040311 040331
h	1 6033	321 053620 2 046332 040367
CYMUDV/5C4020	1 0036	
	e e	2 BLANKSCOMMON
CACCBY/5C4020	1 0036	647 C03670 0 040377 040407
Caucha ta Chann		Z BLANKSCOMMON
CAMCDV/5C4020	1 0036	671 003716 0 040410 040416
CONCATINSFO	1 0037	2 BLAGKSCOMMON
SETT NT/SCHOZO		C71 C04123
		2 BLANK SCOMMON
Cholly/sc4g2g	1 0041	124 054286 . 0 040447 040463
		2 BLANKSCUMMON
CHONEN/SC402D	1 0042	207 004614 0 040464 040535
•_		Z BLANKSCOMMON
CL[NRY/SC40?0		615 808470 0 040636 040651
Cuesti a se car co	3 666	Z BLANKYCOMMON
CYSCLV/SC4D20		471 005673 <u>0 040652 040706</u>
C. (21 V 42 C 8 C 2 C	3 666	
CASCLV/SC4026	<u>1</u> 0056	674 006076 0 040701 040727
CERNLY/SC4020		Z BLANK\$COMMON 077 064253
	• ,0220	ALE APPREAR TO BE CAREAS PARTIES

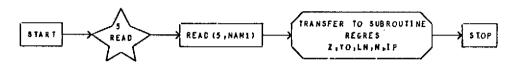
TABLE 5. (Continued)

				2	BLANKSCOMMON
				-	
CERKEN/SC4020	, 1	006254 0063	63	0	C40743 040760 /
				2	BLANKSCOMMON '
C56 TCV/SC4020	1	004364 3064	24	Ü	040761 04677L
				2	BLANKSCOMMON
CSE147/SC4020	1 .	006425 0045	93	е.	543772 C41806
232 - 111 20 - 212			• • • • • • • • • • • • • • • • • • • •	Z	BLANKSCUMMON
CAAXIS/SCHD2D	1	006504 0057	a 7	ū	241007 041042
CVEXTOVERIORE		000001 0000	3,	Z	BLANKSCOMMON
		201210 6-31	. 1	פֿ	241043 041042
VCHARY/504020	l	006710 0071		_	
31165A12640,0	1	007154 0074		0	041043 041111
eelotK/SC+022	1	ᲝᲗᲒᲧᲜᲜ Ტ Ნ १ ୩	65 <u>-</u>	0.	041112 041471
			•	2	BLASKICOMMON
CERAM/SC9020	1	007466 0077	უნ	Ð	841472 B41555
	3 '	666		2	REANKSCOMMON
CCANRAZSCH020	1	007706 0577	57	0	041567 041570
	3	666		2	3LANK SCUMMON
TABLIVISCHUZU	.			٥.,	E41571 042111
NBBCV*/FOR57	1.	007760 0101	13	2	542112 042151
METV&/FOR	i	010114 0101		-	
VC€3577856C57	ì	010137 0103		2	842152 842177
	-	010304 0104		9	042200 042201
1-10K5/858C5/	į.			u u	042203 042201
かうちょしるノトンス	1	010475 0195			
HURDAB/FJH	1	010237 0102	66	_	
No. 508/108				2	042202 044403
NCERTAIFURS7	i	010567 0110		2	044404 044473
1117 [U3/M3FC55	1	011055 0115	53	2	044474 044515
CFEGTY/SC4J2U	1	011254 0114	36	a .	044210 044554
	Э	ធ្វត់ក្		2	BLANKICOMHON
CL1::577504023	1	011437 0120	22	O.	<u></u>
				2	おともいくうじひゃかい
YSSEVIZSEMBLE	1	017923 0121	4:	9	544034 544644
•	3	666		2	∂LªNKSCO4NON
ASCEVI/SCHO2E	1	912142 9122	57	D D	944645 944655
	3	666		2	BLANKSCORMON
CAPLOT/SC4JZD	ī	012250 0125	. 1 1	ā	041650 014731
CAPERIARCADER	3	566 566		2	BLANKSCOMMON
C			1.4	Ď	241732 044750
CAPRNI/SCHOZO	•	012534 0126	10	-	-
			_	2	BLARKSCOAMON
CPRNIV/SC4020	ı	012617 0112	l a	0	044751 045005
	3	GGG		2	BLANKSCOMMON
CGRUIV/SC4JZ J		013211 0141	15		
	3	666		2	в∟а≒К≯СОММОн
C0X0Y7/5C4020	1	014116 0142	10	D	<u> </u>
				2	BLACKSCUMMON
Carity/School	1	014711 3190	112	0	045207 045222
	š	666		2	BLANKSCOMMON
CMARGN/504020	1	015013 0159	71	ø.	049223 045264
***************************************				Ž ĺ	ELANKSCOMMUN
CNBLNK/5C4020	j	015072 0151	41	9	745265 045300
CHDCHK/3C+080		0.004% 6121	• •	2	8LALKS(0MMON
N		n.C.d. 5:-3		ű	645301 045311
BHOV/MSFC	1	015142 3152		يا 2	
					BF#MK2C3WWOM
TRACÉ	. ,	015223 9153	16	0	245312 245317
				2	045320 045402
SPCFRH/MSFC				û	045403 045456

TABLE 5. (Concluded)

CTOSCOZMSEC	i	015347	015645	0	045457 045630	
HOXETH/CSC -		015646	014500	- 0	045631 045647	W 00-40-80-0 4
CIDENT/SCHO2D	i	016501	017653	0	045650 046033	
•••	3	666		2 .	BLANKSCOMMON	,
NOTINS/ESECSS	. 1	017654	020204	2	046034 046044	
NOUT\$/MSEC57		- 020205	021105		ეყბეყნ უყბე/ბ	
NEWIS/ESEC57	1	021167		ż	946077 046115	
NIUERS/HSFCb/	i	022075	022254	2	045116 046240	
RECHES/MSECS/	1	022255	223073	2	046241 046415	
•				4	946415 946467	
NTABS/MSFC55				2	046470 046556	
- PL1の83/85FC57 - 15					-046557 046770	
512213/F0855	1	024641		2	046771 047002	
RE XHS3/FOR57	ì	024701	324764	2	047003 047012	
-666 (COMMON A£OCK	C)				047013 047140	
CaUIKE/SC4020	i	024765	025402	. 0	047147 047231	
	3	GEG		2	BLANKSCUMMON	
insat/scap2p					047232 051027	
- ROCONLIGRAMERCSS	1	026646	027755	2	Q51030 Q51614	
NIESS/FORUZ	1	027756		2	051615 051744	•
NUWSFS/FOR51	1	030041	930100			
EROS/SSECSS						•
かたらんダブドロスジブ	' ' 1	030101,	្ ព្ធ១៥៤៦	2	051745 052121	
SERUKACOHNON (CO)	MON BLOCK)					
6441ML	i	030436	030633	0	052122 052174	ł
				2	BEAGK SCOMMON	
INVRT	1	030634	931245	0	052175 052376	•
			_	2	BLANKSCOMMON	
1028	. 1	031246		_		_
ROAT	1	. 031251	03:652		052377 052529]
				2	BLANK SCOMMON	
₹£68 £\$. 1	031653	033537		052526 054665	
				2	BLANK BCOMMON	_
MAIN	1	U3354 0	033550	0	054666 055017	-
				2	BLANKECOMMON	
SYSSORLIUF. LEVEL	K 5 7 - 13					
END OF COLLECTION		97 SECONO	S		•	
EXQT AA T					n	
4.5						





BIMENSIONED VARIABLES

SYMBOL	STORAGES	SYMBOL	STORAGES	SYMBOL	STORAGES	SYMBOL	STORAGES	SYMBOL	STORAGES
ADARY	22	PHA X	15	FLDX	12	FLDT	12	×	1 5
z	3,15	ZBAR	3,3	ZZBAR	2,3	SHALLZ	101M	SHAL Z1	IDIN
SMAL 22	IDIM	SH A T	12,12	10	15	SYHAT	12,1	YC	15
BZ	15	RESID	15	В	3,3	A	2,3		

Figure 4. Operation of the computer program (cross product).

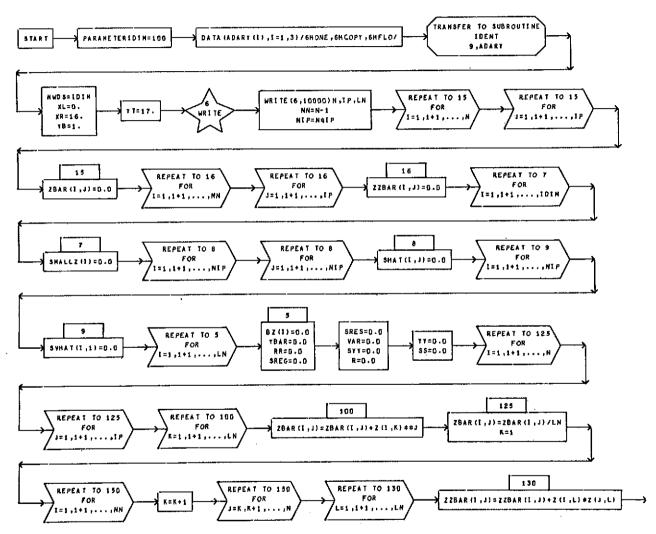


Figure 4. (Continued)

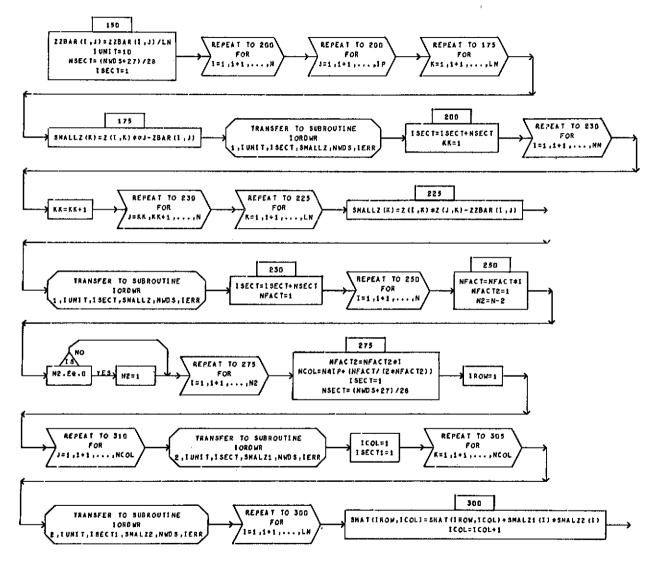


Figure 4. (Continued)

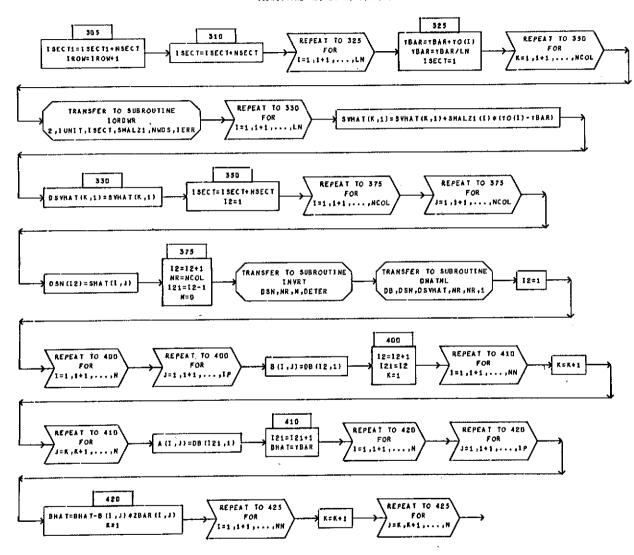


Figure 4. (Continued)

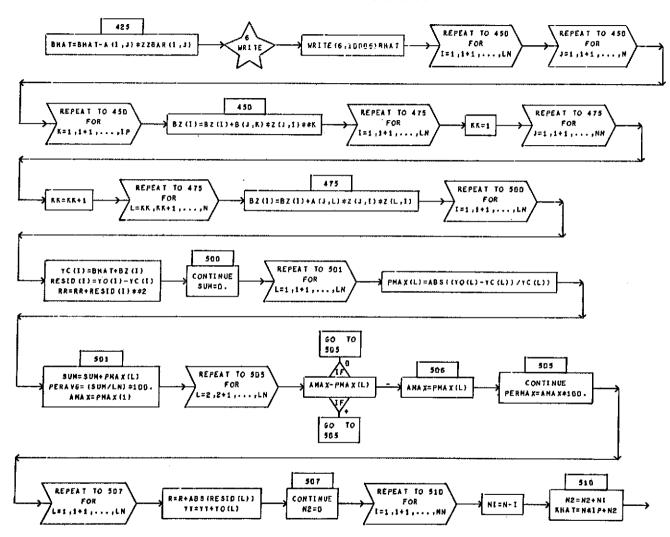


Figure 4. (Continued)

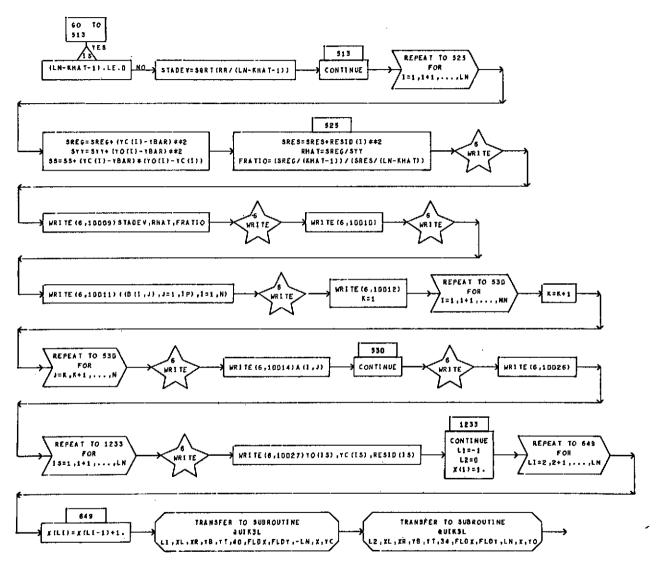
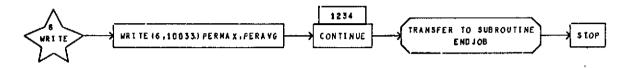


Figure 4. (Continued)

SUBROUTINE REGRES (Z.YO,LN,N,IP)



GENERAL FORTRAN I/O PACKAGE

EXEC VIII

APRIL :1970

READ/WRITE MAG TAPE OR DRUM IN FORTRAN OR NON-FORTRAN FORMAT.

ATHENSIANED VARIABLES

SIMBOL	STORAGES"	STHBOL	STORAGES	SYMBOL	STORAGES	SYMBOL	STORAGES	SYMBOL	STORAGES
ARRAY	1	1 C WD	3	IFLD	29	KODE	6	,I PACK T	
NTWD	3								

Figure 4. (Continued)

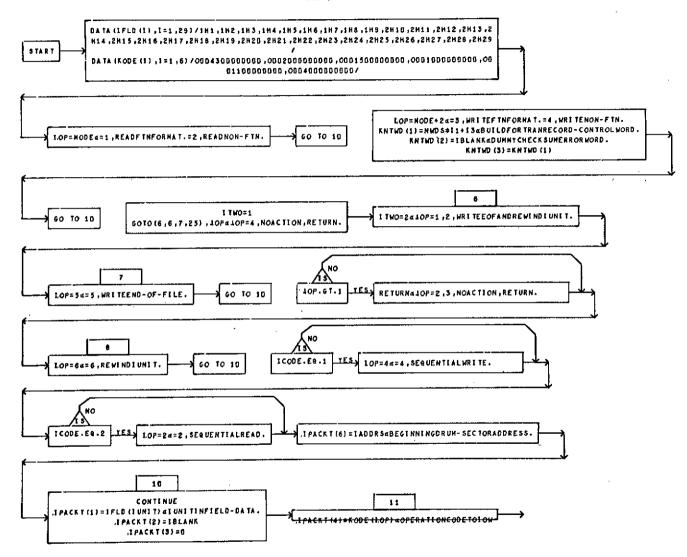


Figure 4. (Continued)

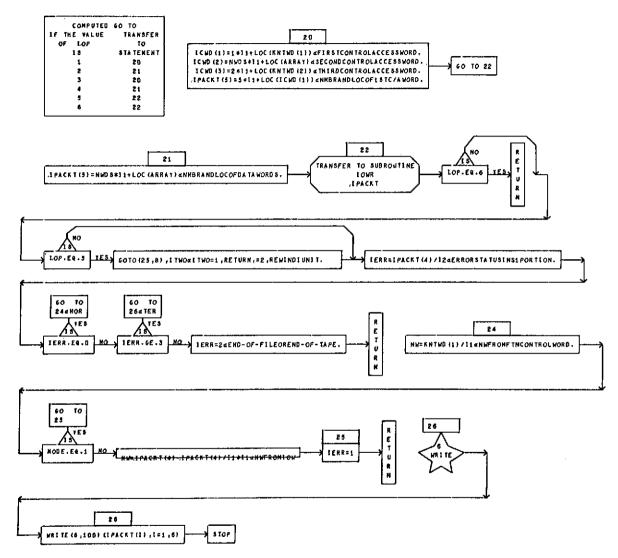


Figure 4. (Continued)

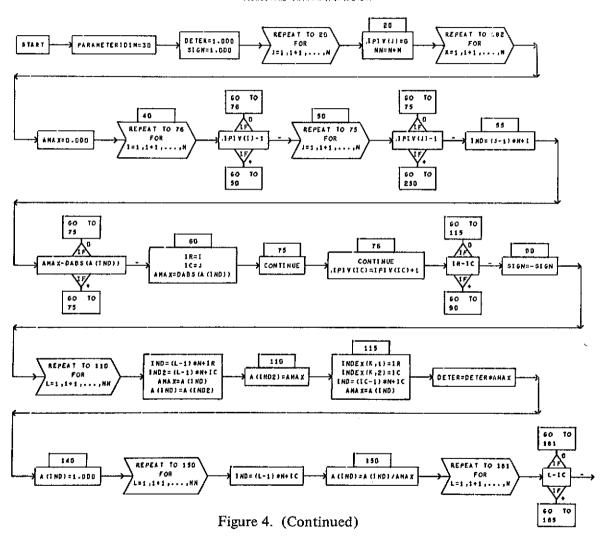
DIMENSIONED VARIABLES

STABOL	STORAGES	STHBOL	STORAGES	SYMBOL	STORAGES	STHBOL	STORAGES	ST MB OL	STORAGES
.1PI ¥	IDLM	1 NDE X	1014,2						

16

Figure 4. (Continued)

SUBROUTINE INVRT (A, M, M, DETER)



SUBROUTINE INVETA, N. N. DETER)

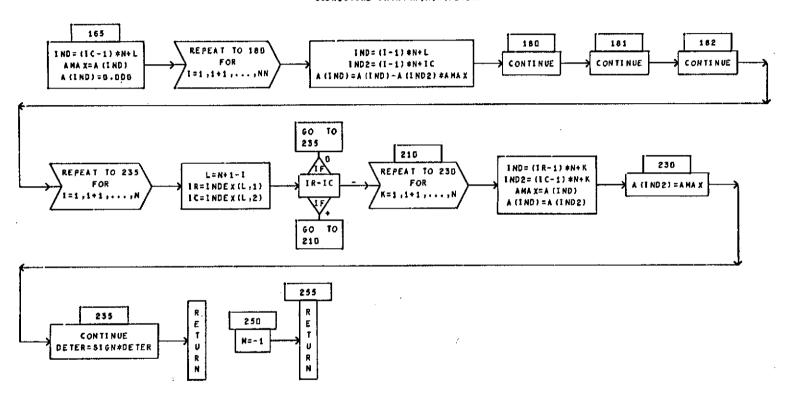


Figure 4. (Continued)

DIMENSIONED VARIABLES



SUBROUTINE DHATHL (C,A,B,N,N,K)

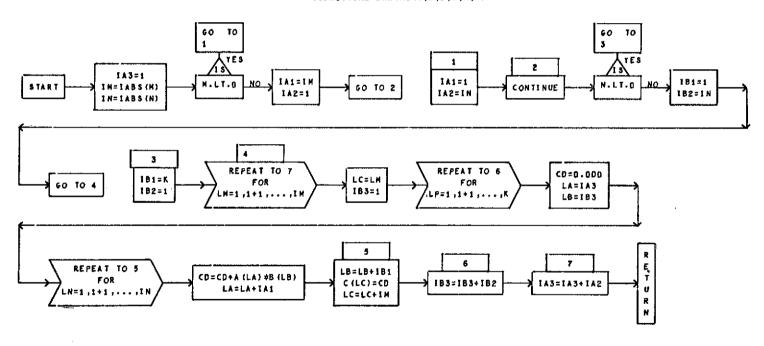


Figure 4. (Concluded)

From equation (38) the following set of input data (Table 6) was developed, containing exact dependent variable values (to three decimal places) for arbitrary values of the three independent variables. In as far as was possible the problem selected in Appendix A was duplicated for comparison purposes.

TABLE 6. INPUT DATA, DEPENDENT VARIABLE VALUES

Data Point Number	Y	X	X ₂	x ₃
1	6.759	0.5	0.4	0.4
2	8.251	0.6	0.3	0.2
3	4.256	0.2	0.6	0.6
4	4.892	0.2	0.6	0.5
5	13.165	0.9	0.0	0.5
6	9.669	0.7	0.0	0.6
7	6.070	0.3	0.9	0.7
8	12.588	0.9	0.3	0.6
9	5.749	0.5	0.6	0.7
10	8.561	0.3	0.8	0.2
1 1	11.333	0.2	0.9	0.0
12	10.589	0.8	0.5	0.6
13	16.117	0.9	0.8	0.3
14	3.525	0.1	0.4	0.7
15	2.333	0.0	0.5	0.8

The input for this sample program was read in through namelist NAM1 as follows:

```
$NAM1

Z = 0.5, 0.4, ..., 0.8,

YO = 6.759, 8.251, ..., 2.333,

LN = 15,

N = 3,

IP = 3,
```

Col. 2

The computed results are shown in Table 7 for this example problem and the plotted results are shown in Figure 5.

TABLE 7. OUTPUT DATA LISTING FOR ILLUSTRATIVE PROBLEM (CASE WITH CROSS PRODUCTS)

HATE .900033772+01			
TANDARO DEVIATION#	.945426711-05 MULT	TPLE CORRELATION COEFFICIENT . 100000000+01 F RATIO335245672	2+17
COEFFICIENTS 660040036+01 -695985709+01	•6999765 <u>0</u> 4+01 ••600018770+01	.500027460+01	-
COEFFICIENTS			
.505020425+0 .506044143+0 595971730+01			
OBSEKVED	COMPUTED	RESIDUAL	
.6/590000n+01			
.825 40005+01	.825100231+31	226477650-gs	
.425599998+01	.425599375+01	.673532466=05	
+48920QQQZ+01	.4892054279+31	26az20901-gs	
.131450000+02	*131649 9 94+02	•54904448-09	
.966900001+01	,766900027+01	238418579-08	
•656999999+0L	•607000053+01,	536441803-06	
. (258A3001+02	•1258B00g8+g2	-,715255737-06	
•57- 980081 +01	•574900067+91	655651093-06	
8560999999+01	+854100559+01	559283661-95	
.113329999+02	+113329972+02	•274181366-C5	
-10599UD00+0 <i>2</i>	·105890093+02	-,357627849-06	
+161170001+02	+161149991+02	•Y53674316-D6	
.352500001+01	•39250054 <i>6+</i> 01	545382580-05	
.2333000000+01	.233299756+01	.244379044-05	

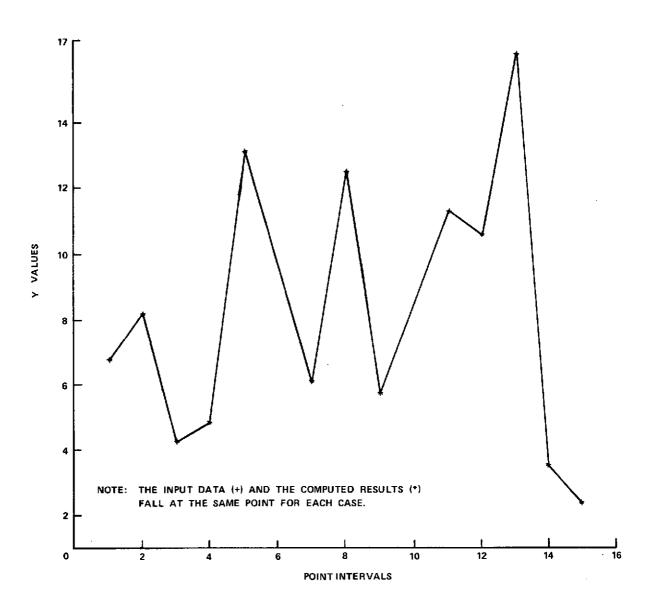


Figure 5. Comparison of input and computed values for illustrative problem with cross products.

The plot graphs the point intervals on the X axis against the exact and computed dependent variables. The exact dependent variables are plotted with (+) and the points are not connected by line segments. The computed dependent variables are plotted with (*) and the points are connected by straight line segments.

Inspection of the digital and plotted results reveals that the computed regression relation yields an almost exact representation of the input data for this arbitrary case. However, experience with several sets of physical data have generally yielded poorer results evidently due to the larger matricies being manipulated and due to unknowns as to whether true linear cross coupling exists in the physical process.

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